

Y-12 NATIONAL SECURITY COMPLEX

CALENDAR YEAR 2002
GROUNDWATER MONITORING
DATA EVALUATION REPORT
FOR THE
U.S. DEPARTMENT OF ENERGY
Y-12 NATIONAL SECURITY COMPLEX,
OAK RIDGE, TENNESSEE

September 2003

Prepared by

ELVADO ENVIRONMENTAL LLC Under Subcontract No. 4300012529

for the

Environmental Compliance Department Environment, Safety, and Health Division Y-12 National Security Complex Oak Ridge, Tennessee 37831

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CONTENTS

Section	<u>Page</u>
List of In-Text Tables	iii
List of Figures	vi
List of Tables	x
List of Acronyms and Abbreviations	xi
1.0 INTRODUCTION	1-1
2.0 BACKGROUND INFORMATION	
2.1 CALENDAR YEAR 2002 MONITORING SUMMARY	
2.1.1 Bear Creek Regime	
2.1.2 East Fork Regime	
2.1.3 Chestnut Ridge Regime	
2.2 TOPOGRAPHY AND BEDROCK GEOLOGY	
2.3 SURFACE WATER DRAINAGE	2-4
2.3.1 Bear Creek	2-4
2.3.2 Upper East Fork Poplar Creek	2-5
2.3.3 Chestnut Ridge	2-6
2.4 GROUNDWATER SYSTEM	2-6
2.4.1 Aquifer	2-6
2.4.1.1 Maynardville Limestone	2-7
2.4.1.2 Knox Group	2-8
2.4.2 Aquitard	
2.5 GROUNDWATER CONTAMINATION	2-11
2.5.1 Bear Creek Regime	2-11
2.5.1.1 S-3 Site	2-11
2.5.1.2 Oil Landfarm WMA	2-12
2.5.1.3 Bear Creek Burial Grounds WMA	2-13
2.5.1.4 Maynardville Limestone Exit Pathway	2-14
2.5.2 East Fork Regime	2-15
2.5.3 Chestnut Ridge Regime	2-17
2.0 CURVEU I ANCE MONTEORING DATA EN AL UATION	2.1
3.0 SURVEILLANCE MONITORING DATA EVALUATION	
3.1 BEAR CREEK REGIME	
3.1.1 Aquitard Monitoring Wells	
3.1.1.1 Inorganic Contaminants	
3.1.1.2 Volatile Organic Compounds	
3.1.1.3 Radioactivity	
3.1.2 Aquifer Monitoring Wells	
3.1.2.1 Inorganic Contaminants	
3.1.2.2 Volatile Organic Compounds	
3.1.2.3 Radioactivity	
3.2 EAST FORK REGIME	
3.2.1 Aquitard Monitoring Wells	
3.2.1.1 Inorganic Contaminants	3-27

3.2.1.2 Volatile Organic Compounds	3-28
3.2.1.3 Radioactivity	
3.2.2 Aquifer Monitoring Wells	
3.2.2.1 Inorganic Contaminants	
3.2.2.2 Volatile Organic Compounds	
3.2.2.3 Radioactivity	
3.2.3 Union Valley	3-46
3.3 CHESTNUT RIDGE REGIME	3-47
3.3.1 Inorganic Contaminants	3-48
3.3.2 Volatile Organic Compounds	3-49
3.3.3 Radioactivity	3-51
4.0 EXIT PATHWAY/PERIMETER MONITORING DATA EVALUATION	
4.1 BEAR CREEK REGIME	
4.1.1 Upper Bear Creek	
4.1.2 Middle Bear Creek	
4.1.3 Lower Bear Creek	
4.2 EAST FORK REGIME	
4.2.1 Groundwater	
4.2.2 Surface Water	
4.3 CHESTNUT RIDGE REGIME	
4.3.1 Groundwater	
4.3.2 Surface Water	4-14
5.0 GROUNDWATER QUALITY TREND EVALUATION	5-1
5.1 BEAR CREEK REGIME	
5.2 EAST FORK REGIME	
5.3 CHESTNUT RIDGE REGIME	
6.0 CONCLUSIONS AND RECOMMENDATIONS	6-1
7.0 REFERENCES	7-1
APPENDIX A: FIGURES	

APPENDIX A: FIGURES APPENDIX B: TABLES

List of In-Text Tables

Tab	<u>le</u> Pi	age
1.	CY 2002 sampling locations in the Bear Creek Regime	2-2
2.	CY 2002 sampling locations in the East Fork Regime, north of Pine Ridge, and in Union Valley	2-2
3.	CY 2002 sampling locations in the Chestnut Ridge Regime	2-3
4.	CY 2002 surveillance monitoring wells with significant differences between conventional sampling and low-flow sampling results for the principal groundwater contaminants	3-1
5.	Bear Creek Regime CY 2002: principal groundwater contaminants detected in surveillance monitoring aquitard wells	3-3
6.	Bear Creek Regime CY 2002: elevated nitrate and uranium concentrations in surveillance monitoring aquitard wells	3-3
7.	Selected nitrate and uranium results for well GW-243	3-4
8.	Bear Creek Regime CY 2002: maximum VOC concentrations in surveillance monitoring aquitard wells	3-6
9.	Selected conventional sampling and low-flow sampling VOC results for well GW-626	3-9
10.	Selected VOC results for wells GW-288 and GW-289	-11
11.	Conventional sampling and low-flow sampling VOC results for well GW-082	-12
12.	Bear Creek Regime CY 2002: elevated gross alpha and gross beta activity in surveillance monitoring aquitard wells	-13
13.	Bear Creek Regime CY 2002: principal groundwater contaminants detected in surveillance monitoring aquifer wells	-15
14.	Bear Creek Regime CY 2002: elevated nitrate and uranium concentrations in surveillance monitoring aquifer wells	-16
15.	Bear Creek Regime CY 2002: maximum VOC concentrations in surveillance monitoring aquifer wells	-20
16.	Bear Creek Regime CY 2002: elevated gross alpha and gross beta activity in surveillance monitoring aquifer wells	-23
17.	East Fork Regime CY 2002: principal contaminants detected in surveillance monitoring aquitard wells	-27

List of In-Text Tables (continued)

18. East Fork Regime CY 2002: elevated nitrate and uranium concentrations in surveillance monitoring aquitard wells	. 3-27
19. East Fork Regime CY 2002: maximum VOC concentrations in surveillance monitoring aquitard wells	. 3-29
20. Selected VOC results for well GW-633	. 3-30
21. Geochemical indicators for biodegradation of chlorinated solvents in well GW-782	. 3-31
22. Selected VOC results for well GW-658	. 3-32
23. East Fork Regime CY 2002: elevated gross alpha and gross beta radioactivity in surveillance monitoring aquitard wells	. 3-34
24. East Fork Regime CY 2002: principal contaminants detected in surveillance monitoring aquifer wells	. 3-36
25. East Fork Regime CY 2002: elevated nitrate and uranium concentrations in surveillance monitoring aquifer wells	. 3-36
26. East Fork Regime CY 2002: maximum VOC concentrations in surveillance monitoring aquifer wells	. 3-40
27. Selected VOC data for well GW-605	. 3-42
28. East Fork Regime CY 2002: elevated gross alpha and gross beta activity in surveillance monitoring aquifer wells	. 3-44
29. Union Valley CY 2002: principal groundwater contaminants detected at surveillance monitoring sampling locations	. 3-46
30. Chestnut Ridge Regime CY 2002: principal groundwater contaminants detected in surveillance monitoring wells	. 3-47
31. Geochemical characteristics indicative of potential grout contamination in wells GW-205 and GW-757	. 3-48
32. Chestnut Ridge Regime CY 2002: maximum concentrations of VOCs in surveillance monitoring wells	. 3-49
33. Total potassium concentrations and beta radioactivity in wells GW-205, GW-221 and GW-757	. 3-52

List of In-Text Tables (continued)

<u>Tabl</u>	<u>e</u> <u>P</u>	age
34.	Bear Creek Regime CY 2002: sampling locations used for exit pathway/perimeter monitoring	4-1
35.	Upper Bear Creek CY 2002: maximum contaminant concentrations	4-2
36.	Middle Bear Creek CY 2002: maximum contaminant concentrations	4-3
37.	Results of radiological analyses of surface water samples collected from Middle Bear Creek in March 2002	4-5
38.	Lower Bear Creek CY 2002: maximum contaminant concentrations	4-6
39.	Summary statistics for uranium concentrations in well GW-715	4-7
40.	East Fork Regime CY 2002: sampling locations for exit pathway/perimeter monitoring	4-8
41.	East Fork Regime CY 2002: types of contaminants detected at the exit pathway/perimeter sampling locations	4-9
42.	East Fork Regime CY 2002: maximum VOC concentrations in exit pathway/perimeter monitoring wells	4-9
43.	East Fork Regime CY 2002: maximum contaminant concentrations at the UEFPC exit pathway/perimeter sampling locations	l-12
44.	Chestnut Ridge Regime CY 2002: sampling locations used for exit pathway/perimeter monitoring	l-13
45.	Bear Creek Regime CY 2002: sampling locations with increasing contaminant concentration trends	5-1
46.	East Fork Regime CY 2002: sampling locations with increasing contaminant concentration trends	5-4

List of Figures

<u>Figure</u>	<u>Page</u>
A.1	Hydrogeologic regimes at the Y-12 National Security Complex
A.2	CY 2002 sampling locations in the Bear Creek Hydrogeologic Regime
A.3	CY 2002 sampling locations in the Upper East Fork Poplar Creek Hydrogeologic Regime and in Union Valley
A.4	Westbay [™] monitoring system sampling port depths in well GW-722
A.5	CY 2002 sampling locations in the Chestnut Ridge Hydrogeologic Regime A-5
A.6	Topography and bedrock geology near the Y-12 National Security Complex A-6
A.7	Fill areas and pre-construction drainage features in the Upper East Fork Poplar Creek Hydrogeologic Regime
A.8	Seasonal groundwater elevations in the Bear Creek Hydrogeologic Regime, 2002
A.9	Seasonal groundwater elevations in the Upper East Fork Poplar Creek Hydrogeologic Regime, 2002
A.10	Seasonal groundwater elevations in the Chestnut Ridge Hydrogeologic Regime, 2002 A-10
A.11	Generalized extent of nitrate in groundwater near the Y-12 National Security Complex A-11
A.12	Generalized extent of volatile organic compounds in groundwater near the Y-12 National Security Complex
A.13	Generalized extent of gross alpha activity in groundwater near the Y-12 National Security Complex
A.14	Generalized extent of gross beta activity in groundwater near the Y-12 National Security Complex
A.15	Concentrations of inorganic contaminants in wells GW-276 and GW-537
A.16	Concentrations of selected VOCs in wells GW-243 and GW-087 A-16
A.17	Concentrations of selected VOCs in well GW-071
A.18	Gross alpha and gross beta activity in well GW-243
A.19	Nitrate concentrations in Exit Pathway Picket C wells

List of Figures (continued)

<u>Figure</u>	<u>2</u>	<u>Page</u>
A.20	Nitrate concentrations in well GW-725	A-20
A.21	Nitrate concentrations in well GW-226	A-21
A.22	Nitrate concentrations in well GW-225	A-22
A.23	Nitrate concentrations in Exit Pathway Picket B wells	A-23
A.24	Nitrate concentrations in well GW-706	A-24
A.25	Uranium concentrations in wells GW-694 and GW-706	A-25
A.26	Nitrate and uranium concentrations in Exit Pathway Picket A wells	A-26
A.27	Concentrations of TCE in Exit Pathway Picket C wells	A-27
A.28	Concentrations of TCE in well GW-725	A-28
A.29	Concentrations of TCE in well GW-226	A-29
A.30	Concentrations of TCE in wells GW-703 and GW-704	A-30
A.31	Gross alpha activity in well GW-694	A-31
A.32	Nitrate concentrations and gross beta activity in well GW-633	A-32
A.33	Nitrate concentrations in well GW-108	A-33
A.34	Concentrations of PCE in well GW-791	A-34
A.35	Gross alpha activity in well GW-782	A-35
A.36	Nitrate concentrations in well GW-251	A-36
A.37	Concentrations of VOCs in well GW-620	A-37
A.38	Concentrations of VOCs in well GW-698	A-38
A.39	Benzene concentrations in well GW-193	A-39
A.40	Concentrations of CTET in well GW-605	A-40
A.41	Concentrations of PCE and chloroform in well GW-605	A-41

List of Figures (continued)

<u>Figure</u>		<u>Page</u>
A.42	Concentrations of CTET and chloroform in well GW-606	A-42
A.43	Concentrations of CTET and chloroform in well GW-381	A-43
A.44	Concentrations of VOCs in well GW-382	A-44
A.45	Concentrations of PCE and TCE in well GW-223	A-45
A.46	Concentrations of CTET and chloroform in well GW-153	A-46
A.47	Gross beta activity in well GW-154	A-47
A.48	Concentrations of CTET and chloroform in well GW-170	A-48
A.49	Concentrations of 111TCA in well GW-177	A-49
A.50	Contaminant concentrations in Bear Creek	A-50
A.51	Concentrations of VOCs in well GW-722 sampling ports 14, 17, 20, and 22	A-51
A.52	Arsenic concentrations in McCoy Branch at MCK 2.0 and MCK 2.05	A-52
A.53	Concentrations of PCE and TCE in well GW-008	A-53
A.54	Gross alpha activity in well GW-061	A-54
A.55	Concentrations of selected VOCs in well GW-071	A-55
A.56	Concentrations of 11DCA in well GW-072	A-56
A.57	Concentrations of selected VOCs in well GW-082	A-57
A.58	Nitrate concentrations and gross beta activity in well GW-085	A-58
A.59	Gross beta activity in well GW-537	A-59
A.60	Concentrations of PCE in well GW-627	A-60
A.61	Concentrations of 12DCE in well GW-653	A-61
A.62	Nitrate concentrations and gross beta activity in well GW-695	A-62

List of Figures (continued)

Figure		<u>Page</u>
A.63	Gross beta activity in well GW-703	A-63
A.64	Concentrations of TCE in well GW-706	A-64
A.65	Uranium concentrations and gross alpha activity in well GW-715	A-65
A.66	Concentrations of TCE in spring SS-4	A-66
A.67	Tc-99 activity in well GW-108	A-67
A.68	Concentrations of CTET and PCE in wells GW-151 and GW-220	A-68
A.69	Uranium concentrations and gross alpha activity in well GW-154	A-69
A.70	Concentrations of uranium and 12DCE in well GW-223	A-70
A.71	Concentrations of 12DCE and VC in well GW-253	A-71
A.72	Concentrations of PCE in well GW-383	A-72
A.73	Nitrate concentrations in well GW-606	A-73
A.74	Concentrations of benzene and 12DCE in well GW-633	A-74
A.75	Concentrations of c12DCE in well GW-698	A-75
A.76	Concentrations of PCE, TCE, and 11DCE in well GW-762	A-76
A.77	Concentrations of CTET and PCE in well GW-769	A-77
A.78	Concentrations of 11DCA and 11DCE in well GW-177	A-78
A.79	Concentrations of 111TCA, 11DCA, and 11DCE in well GW-305	A-79
A.80	Concentrations of PCE, 11DCE, and 12DCE in well GW-798	A-80

List of Tables

<u>Table</u>		<u>Page</u>
B.1	CY 2002 sampling dates for groundwater and surface water sampling locations in the Bear Creek Hydrogeologic Regime	B-1
B.2	CY 2002 sampling dates for groundwater and surface water sampling locations in the Upper East Fork Poplar Creek Hydrogeologic Regime	B-5
B.3	CY 2002 sampling dates for groundwater and surface water sampling locations in the Chestnut Ridge Hydrogeologic Regime	B-9
B.4	Concentration trends for the principal contaminants detected at CY 2002 sampling locations in the Bear Creek Hydrogeologic Regime	B-13
B.5	Concentration trends for the principal contaminants detected at CY 2002 sampling locations in the Upper East Fork Poplar Creek Hydrogeologic Regime	B-15
B.6	Concentration trends for contaminants detected at CY 2002 sampling locations in the Chestnut Ridge Hydrogeologic Regime	B-17

List of Acronyms and Abbreviations

BCBG Bear Creek Burial Grounds

BCV Bear Creek Valley
BCK Bear Creek kilometer

Bear Creek Regime Bear Creek Hydrogeologic Regime

BG Burial Ground

bgs below ground surface

BJC Bechtel Jacobs Company LLC

BT buried tributary
BWXT BWXT Y-12, L.L.C.
CE counting error

CERCLA Comprehensive Environmental Response, Compensation, and Liability Act

Chestnut Ridge Regime Chestnut Ridge Hydrogeologic Regime

CRSP Chestnut Ridge Security Pits

CTET carbon tetrachloride
CY calendar year
yd³ cubic yards
DMB dimethylbenzene

DNAPL dense nonaqueous phase liquids
DOE U.S. Department of Energy
data quality objective

East Fork Regime Upper East Fork Poplar Creek Hydrogeologic Regime EMWMF Environmental Management Waste Management Facility

ETB ethylbenzene

FCAP Filled Coal Ash Pond

ft feet

ft/d feet per day gpm gallons per minute

GWMR Groundwater Monitoring Report
GWPP Groundwater Protection Program
HCDA Hazardous Chemical Disposal Area

K-40 potassium-40

LMES Lockheed Martin Energy Systems, Inc.

LRSPW Lake Reality Spillway MC methylene chloride

 $\begin{array}{ll} MCL & maximum \ contaminant \ level \\ MDA & minimum \ detectable \ activity \\ mgd & million \ gallons \ per \ day \\ \mu g/L & micrograms \ per \ liter \\ mg/L & milligrams \ per \ liter \\ \end{array}$

MMES Martin Marietta Energy Systems, Inc.

mrem/yr millirems per year
msl mean sea level
mV millivolts
NHP New Hope Pond

NPDES National Pollution Discharge Elimination System

NT North Tributary (Bear Creek)

List of Acronyms and Abbreviations (continued)

OF Outfall

ORNL Oak Ridge National Laboratory

ORR Oak Ridge Reservation
PCE tetrachloroethene
pCi/L picoCuries per liter
pCP post-closure permit

RCRA Resource Conservation and Recovery Act

REDOX oxidation-reduction potential

ROD record of decision
SCR south Chestnut Ridge
SDWA Safe Drinking Water Act
SS south side (of Bear Creek)
SWDF solid waste disposal facility

TCE trichloroethene

TCFM trichlorofluoromethane

Tc-99 technetium-99

TDEC Tennessee Department of Environment and Conservation

TDS total dissolved solids

Th-234 thorium-234

UEFPC Upper East Fork Poplar Creek
UNCS United Nuclear Corporation Site

UST underground storage tank

U-234 uranium-234 U-238 uranium-238 VC vinyl chloride

VOC volatile organic compound WCPA Waste Coolant Processing Area

WMA waste management area

WRRP Water Resources Restoration Program Y-12 Y-12 National Security Complex

111TCA 1,1,1-trichloroethane
11DCA 1,1-dichloroethane
11DCE 1,1-dichloroethene
12DCA 1,2-dichloroethane
12DCE 1,2-dichloroethene
c12DCE cis-1,2-dichloroethene
t12DCE trans-1,2-dichloroethene

1.0 INTRODUCTION

This report addresses the evaluation of groundwater and surface water monitoring data obtained at the U.S. Department of Energy (DOE) Y-12 National Security Complex (Y-12) during calendar year (CY) 2002. Provisions of DOE Order 5400.1 (*General Environmental Protection Program*) require the evaluation of monitoring data to determine: (1) the quality of groundwater and surface water in areas that are (or could be) affected by Y-12 operations, (2) the quality of groundwater and surface water in areas where contaminants from Y-12 are most likely to migrate beyond the DOE Oak Ridge Reservation (ORR) property line, and (3) long-term trends in the quality of groundwater at Y-12. Section 2 (*Background Information*) of this report provides the overall hydrogeologic context for the respective monitoring data evaluations presented in Section 3 (*Surveillance Monitoring Data Evaluation*), Section 4 (*Exit Pathway/Perimeter Monitoring Data Evaluation*), and Section 5 (*Groundwater Quality Trend Evaluation*). The significant findings of each data evaluation are summarized in Section 6 (*Conclusions and Recommendations*) and Section 7 (*References*) lists the technical reports and documents cited for more detailed information. Referenced illustrations (maps and trend graphs) and data tables are presented in Appendix A and Appendix B, respectively.

2.0 BACKGROUND INFORMATION

The following sections provide information relevant to groundwater and surface water quality monitoring in three hydrogeologic regimes at Y-12 (Figure A.1): the Bear Creek Hydrogeologic Regime (Bear Creek Regime), the Upper East Fork Poplar Creek Hydrogeologic Regime (East Fork Regime), and Chestnut Ridge Hydrogeologic Regime (Chestnut Ridge Regime). Included are a summary of the CY 2002 groundwater and surface water sampling and analysis activities in each regime; a short description of the topography and geology in each regime; an overview of the hydrogeologic system in each regime; and a discussion of the extent of groundwater contamination in each regime.

2.1 CALENDAR YEAR 2002 MONITORING SUMMARY

Groundwater and surface water quality monitoring in the Bear Creek, East Fork, and Chestnut Ridge hydrogeologic regimes during CY 2002 was performed by: (1) the Y-12 Groundwater Protection Program (GWPP), which is managed by BWXT Y-12, L.L.C. (BWXT), (2) the ORR Water Resources Restoration Program (WRRP), which is managed by Bechtel Jacobs Company LLC (BJC), and (3) the BJC subcontractor(s) responsible for the operation of the Environmental Management Waste Management Facility (EMWMF) in the Bear Creek Regime and several nonhazardous waste landfills located in the Chestnut Ridge Regime. Sampling and analysis activities were performed by the GWPP to directly support the monitoring data evaluations required under DOE Order 5400.1, whereas BJC and the BJC subcontractors implemented the groundwater sampling and analysis activities required to comply with requirements of the Resource Conservation and Recovery Act (RCRA), the Comprehensive Environmental Response, Compensation, and Recovery Act (CERCLA), and the Tennessee Department of Environment and Conservation (TDEC) regulations governing nonhazardous solid waste disposal facilities (SWDFs). Respective groundwater sampling and analysis activities performed by each organization were coordinated to achieve mutual programmatic objectives, including the use of functionally equivalent sampling procedures and laboratory analytical methods. Thus, the monitoring results obtained by each organization are suitable to the data evaluations required under DOE Order 5400.1.

The following sections identify the programmatic drivers for groundwater and surface water quality monitoring in each hydrogeologic regime during CY 2002 and the associated sampling locations and frequency. The CY 2002 Groundwater Monitoring Report (GWMR) issued by the Y-12 GWPP provides detailed sampling and analysis information, including the sampling procedures, field measurements, and laboratory analytes, along with references to the documentation containing equivalent information for the groundwater sampling and analysis activities managed by BJC (BWXT 2003a).

2.1.1 Bear Creek Regime

Groundwater and surface water monitoring in the Bear Creek Regime during CY 2002 was performed: (1) as needed to support the monitoring data evaluation requirements of DOE Order 5400.1; (2) in accordance with the groundwater monitoring requirements defined in the RCRA post-closure permit (PCP) for the Bear Creek Regime (permit number TNHW-087); and (3) for CERCLA groundwater monitoring purposes, including monitoring at the EMWMF, which is a landfill constructed to receive hazardous waste and mixed-waste generated during CERCLA remedial actions on the ORR. As shown below in Table 1, a total of 67 monitoring wells, six springs, and 17 surface water stations in the Bear Creek Regime were sampled during

CY 2002 for the purposes of DOE Order 5400.1 monitoring, RCRA monitoring, and CERCLA monitoring.

Monitoring Driver	Monitoring Wells	Springs	Surface Water Stations
DOE Order 5400.1 RCRA CERCLA	39 8 20	3 0 3	6 0 11

17

67

Totals:

Table 1. CY 2002 sampling locations in the Bear Creek Regime

Note that the GWPP sampling and analysis activities are focused on a single hydrogeologic regime at Y-12 on a rotating annual basis (i.e., once every three years), and the Bear Creek Regime was the focus in CY 2002. Figure A.2 shows the location of each well, spring, and surface water station. Samples were collected semiannually during CY 2002 from most of the sampling locations; two wells, one spring, and eight surface water stations were sampled during only the first quarter of CY 2002, and 14 wells associated with the EMWMF were sampled during the third and fourth quarters of the year. Specific sampling dates are shown on Table B.1.

2.1.2 East Fork Regime

Groundwater and surface water monitoring in the East Fork Regime during CY 2002 was performed: (1) as needed to support the monitoring data evaluation requirements of DOE Order 5400.1; (2) in accordance with the groundwater monitoring requirements defined in the RCRA PCP for the East Fork Regime (permit number TNHW-089); and (3) as required under the CERCLA record of decision (ROD) for Union Valley and as needed for the purposes of CERCLA baseline and remediation effectiveness monitoring. As shown below in Table 2, a total of 52 monitoring wells, two springs, and ten surface water stations in the East Fork Regime (and surrounding areas) were sampled during CY 2002 for the purposes of DOE Order 5400.1 monitoring, RCRA monitoring, and CERCLA monitoring.

Table 2. CY 2002 sampling locations in the East Fork Regime, north of Pine Ridge, and in Union Valley

Monitoring Driver	Monitoring Wells	Springs	Surface Water Stations
DOE Order 5400.1 RCRA CERCLA	32 5 16	0 0 2	6 0 4
Totals:	52	2	10

Note: Samples were collected from one well (GW-722) for DOE Order 5400.1 (February and July) and CERCLA (May and November) monitoring purposes (BWXT 2003a).

Fifty-one of these sampling locations lie within the boundaries of the East Fork Regime (Figure A.3), which is divided into the three major areas for the purposes of this report: the western Y-12 area between Old Bear Creek Road and grid coordinate easting 55,000; the central Y-12 area between grid coordinate eastings 55,000 and 62,000; and the eastern Y-12 area between grid coordinate easting 62,000 and Scarboro Road. The other sampling locations lie outside the boundaries of the regime, including six wells and two springs located in Union Valley east of the ORR boundary at Scarboro Road (Figure A.3), and five surface water stations

located in drainage features along the ORR boundary on the north side of Pine Ridge. Additionally, one of the wells in the eastern Y-12 area (GW-722) contains a WestbayTM multiport sampling system and groundwater samples were collected from ten sampling ports at different depths in the well (Figure A.4). Samples were collected at least semiannually from each CY 2002 sampling location; four of the monitoring wells were sampled quarterly and three wells were sampled only once during the year; specific sampling dates are shown on Table B.2.

2.1.3 Chestnut Ridge Regime

Groundwater and surface water monitoring in the Chestnut Ridge Regime during CY 2002 was performed: (1) as needed to support the monitoring data evaluation requirements of DOE Order 5400.1; (2) in accordance with the groundwater monitoring requirements defined in the RCRA PCP for the Chestnut Ridge Regime (permit number TNHW-088); (3) in accordance with the TDEC regulations governing detection monitoring at nonhazardous SWDFs and the respective operating permits issued by the TDEC for several SWDFs in the regime; and (4) as specified in applicable CERCLA decision documents. As shown below in Table 3, a total of 40 monitoring wells, four springs, and five surface water stations in the Chestnut Ridge Regime were sampled during CY 2002 for the purposes of DOE Order 5400.1 monitoring, SWDF detection monitoring, RCRA monitoring, and CERCLA monitoring.

Table 3. CY 2002 sampling locations in the Chestnut Ridge Regime

Monitoring Driver	Monitoring Wells	Springs	Surface Water Stations
DOE Order 5400.1	0	1	3
SWDF	22	1	0
RCRA	14	0	0
CERCLA	6	2	2
Totals:	40	4	5

Note: Two wells (GW-562 and GW-798) were sampled for SWDF and RCRA monitoring purposes during January and July (BWXT 2003a).

Figure A.5 shows the location of each well, spring, and surface water station. Samples were collected semiannually during CY 2002 from each of these locations except one well (GW-305) that was sampled during each quarter of the year (Table B.3). Samples were collected from the springs and surface water stations during seasonally wet (January-February) and seasonally dry (July-September) flow conditions.

2.2 TOPOGRAPHY AND BEDROCK GEOLOGY

The Bear Creek Regime and the East Fork Regime are each in Bear Creek Valley (BCV), which is bound to the north by Pine Ridge and to the south by Chestnut Ridge (Figure A.6). The Bear Creek Regime encompasses several miles of BCV between the western end of the Bear Creek watershed and a low topographic and hydrologic divide near the west end of Y-12. The East Fork Regime encompasses about three miles of BCV east of this topographic/hydrologic divide and west of the ORR property boundary along Scarboro Road. Ground surface elevations along the axis of BCV in each regime range from about 1,000 feet (ft) above mean sea level (msl) near the topographic/hydrologic divide to about 800 ft above msl where Bear

Creek cuts through Pine Ridge and about 900 ft above msl where Upper East Fork Poplar Creek (UEFPC) cuts through Pine Ridge.

The Chestnut Ridge Regime is on Chestnut Ridge directly south of Y-12 and encompasses a portion of the ridge bordered by BCV to the north, Scarboro Road to the east, Bethel Valley Road to the south, and Dunaway Branch to the west (Figure A.6). The northern flank of the ridge forms a steep slope rising more than 200 ft above the floor of BCV. The crest of the ridge slopes toward the east from an elevation of about 1,200 ft above msl southwest of Y-12 to about 1,060 ft above msl where Scarboro Road crosses the ridge. A series of prominent hills dominates the central part of the broad southern flank of Chestnut Ridge, which gently slopes toward Bethel Valley.

Bedrock geology in the vicinity of Y-12 is characterized by thrust-faulted sequences of southeast-dipping, clastic (primarily shale and siltstone) and carbonate (limestone and dolostone) strata of Lower Cambrian to Upper Ordovician age (Figure A.6). Geologic units in the Bear Creek Regime and the East Fork Regime are the shales and siltstones of the Rome Formation underlying Pine Ridge and the interbedded limestone and shale formations of the Conasauga Group that underlie BCV and the southern flank of Pine Ridge. Carbonates (primarily dolostone) of the Knox Group and the overlying argillaceous limestones and interbedded shales of the Chickamauga Group are the geologic units in the Chestnut Ridge Regime. Strike and dip of bedding in each hydrogeologic regime is generally N55°E and 45°SE, respectively (as referenced to true north).

In BCV, unweathered bedrock is overlain by up to 40 ft of several unconsolidated materials, including alluvium, colluvium, fine-grained residuum, and saprolite (weathered bedrock). Where undisturbed, the saprolite often retains primary textural features of the unweathered bedrock, including fractures (Martin Marietta Energy Systems, Inc. [MMES] 1992). However, extensive areas of cut-and-fill within Y-12 have substantially altered the shallow subsurface in BCV throughout much of the East Fork Regime. Most of the fill, which contains many voids and generally consists of 5 to 25 ft of a heterogeneous mixture of building debris and re-compacted soil/residuum (Sutton and Field 1995), was placed in the tributaries and main channel of UEFPC (Figure A.7).

On Chestnut Ridge, bedrock is overlain by as much as 100 ft of red-brown to yellow-orange residuum. The residuum, which is predominantly composed of clay and hematite, contains semicontinuous relict beds of fractured chert and other lithologic heterogeneities (such as silt bodies) that provide a weakly connected network through which saturated flow can occur (MMES 1992). Also, residuum on Chestnut Ridge is thin or nonexistent near karst features such as dolines (sink holes), swallets (sinking streams), and solution pan features (Ketelle and Huff 1984).

2.3 SURFACE WATER DRAINAGE

The following subsections provide a brief description of surface water drainage systems in the Bear Creek Regime, East Fork Regime, and Chestnut Ridge Regime.

2.3.1 Bear Creek

Surface water in the Bear Creek Regime is drained by Bear Creek and its tributaries (Figure A.2). From its headwaters near the west end of Y-12, Bear Creek flows southwest for approximately 4.5 miles, where it turns

northward to flow into East Fork Poplar Creek. Monitoring locations along the main channel of Bear Creek are specified by the Bear Creek kilometer (BCK) value corresponding to the distance upstream from the confluence with East Fork Poplar Creek (e.g., BCK-09.20). Sections of the main channel are referenced as upper Bear Creek (upstream of BCK-11.84), middle Bear Creek (between BCK-11.84 and BCK-09.20), and lower Bear Creek (downstream of BCK-09.20). Tributaries are designated as north tributary (NT) or south tributary along with a value representing the tributary number counted downstream from the headwaters (e.g., NT-1). Major springs along the south side (SS) of Bear Creek are numbered in ascending order downstream from the headwaters (e.g., SS-1).

Approximately half of the annual precipitation in BCV exits via surface water flow in Bear Creek, and possibly higher proportions during winter and early spring, with the remainder of the annual precipitation lost to evapotranspiration and recharge to the groundwater system (DOE 1997a). Flow in the creek increases rapidly during rainfall and afterward reflects the relative contributions of overland flow, stormflow, and groundwater discharge. Flow in the main channel and tributaries generally returns to pre-precipitation levels within one or two days. Major sections of upper and middle Bear Creek are seasonally dry, but flow is perennial in lower Bear Creek.

The main channel of Bear Creek functions as a major conduit of the shallow karst network within the Maynardville Limestone (DOE 1997a). Discharge from springs located along the Maynardville Limestone/Copper Ridge Dolomite boundary on the north slope of Chestnut Ridge dominate the hydrology of the creek, especially during droughts when springs provide most of the flow in the main channel. Additionally, the main channel contains alternating gaining and losing reaches. Each gaining reach generally correlates with a major groundwater discharge area. Losing reaches in upper and middle Bear Creek, particularly a section of the main channel directly south of Sanitary Landfill I, play an important role in transferring contaminants from Bear Creek into the Maynardville Limestone, which directly underlies the creek throughout much of BCV.

2.3.2 Upper East Fork Poplar Creek

Surface water in the East Fork Regime is drained by UEFPC, which was extensively modified during construction of Y-12 (Figure A.7). The headwaters and several thousand feet of the main channel in the upper reach of UEFPC, including all its northern tributaries in the western and central Y-12 areas, were filled and replaced with an extensive network of underground storm drains. For reference purposes, each buried tributary (BT) of UEFPC is designated with a value (e.g., BT-1) representing the tributary number counted downstream (west to east) from the headwaters. The storm drains direct surface runoff into the exposed portion of the UEFPC channel at several locations. Outfall (OF) 200 is at the beginning of the exposed portion of the UEFPC channel about 6,000 ft upstream of New Hope Pond (NHP)/Lake Reality (Figure A.3). Closed and capped in 1988, NHP was an unlined surface impoundment constructed in 1963 to regulate the quantity and quality of surface water exiting Y-12. Lake Reality is a lined surface impoundment that was built in 1988 to replace NHP.

During normal operations, flow in UEFPC is directed through a concrete-lined distribution channel located around the south and east side of NHP/Lake Reality (Figure A.3). Also, a gravel and perforated pipe underdrain beneath portions of the distribution channel captures shallow groundwater. Until December 1996 when flow was rerouted to bypass Lake Reality, surface flow in the UEFPC distribution channel discharged into Lake Reality (and exited through a weir in the western berm). Beginning in July 1998, flow in the UEFPC distribution channel was permanently diverted through the Lake Reality spillway (LRSPW), which

discharges into the mainstream of UEFPC directly north (downstream) of Lake Reality. Bypassing Lake Reality reduces mercury contributions to dry-weather flow in UEFPC.

About 70% of dry-weather flow in UEFPC, is attributable to once-through non-contact cooling water, condensate, and cooling tower blowdown, and the remaining 30% is from groundwater discharge (Shevenell 1994). Beginning in July 1996 a flow management program was implemented whereby water from the Clinch River is discharged near OF 200 to augment flow in UEFPC, which decreased from as much as 15 million gallons per day (mgd) to about 2.5 mgd because of reduced operations at Y-12 in recent years. Flow management is needed to achieve the National Pollution Discharge Elimination System (NPDES) minimum daily flow requirement of 7 mgd at Station 17, which is where UEFPC exits the ORR downstream from Lake Reality (Figure A.3). Flow management also allows compliance with NPDES toxicity requirements and helps lower the elevated water temperature in UEFPC.

2.3.3 Chestnut Ridge

The Chestnut Ridge Regime encompasses five primary tributary drainage basins on south Chestnut Ridge (SCR), informally numbered from west to east (SCR1 through SCR5): Dunaway Branch (SCR 1) and SCR2 in the western part of the regime, McCoy Branch (SCR3) in the central part of the regime; and SCR4 and SCR5 in the eastern part of the regime (Figure A.5). These tributaries are mainly intermittent at elevations higher than 900 ft above msl. Each receives flow via surface runoff, stormflow discharge, and groundwater baseflow, which increases with distance downstream and includes substantial contributions from springs. All of the tributaries convey surface flow south toward Bethel Valley and discharge into Melton Hill Reservoir (Clinch River) south of the Chestnut Ridge Regime.

2.4 GROUNDWATER SYSTEM

The following overview of the groundwater system near Y-12 is based on the conceptual hydrogeologic models described in *Report on the Remedial Investigation of Bear Creek Valley at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee* (DOE 1997a) and *Report on the Remedial Investigation of the Upper East Fork Poplar Creek Characterization Area at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee* (DOE 1998), both of which incorporate the hydrogeologic framework and associated nomenclature described in *Status Report* — *A Hydrologic Framework for the Oak Ridge Reservation* (Solomon, et. al. 1992).

There are two basic hydrogeologic units in the vicinity of Y-12: the aquifer and the aquitard (Figure A.6). The aquifer is comprised of the uppermost formation of the Conasauga Group (Maynardville Limestone) and the overlying formations of the Knox Group. The aquitard consists of the remaining Conasauga Group formations (Nolichucky Shale, Maryville Limestone, Rogersville Shale, Rutledge Limestone, and Pumpkin Valley Shale) and the underlying Rome Formation. The following discussion provides a short description of each hydrogeologic unit.

2.4.1 Aquifer

Components of the aquifer underlie the axis of BCV (Maynardville Limestone) and form Chestnut Ridge (Knox Group). Separate overviews of the hydrologic characteristics of the Maynardville Limestone and the Knox Group are provided below.

2.4.1.1 Maynardville Limestone

Most groundwater flow in the Maynardville Limestone occurs at depths less than 100 ft below ground surface (bgs) in an extensively interconnected network of solution conduits and cavities (karst network). Flow in the shallow karst network is relatively rapid and occurs as "quickflow" discharge to nearby surface drainage features (e.g., Bear Creek). Below the shallow karst network, fractures provide the primary flowpaths. Also, there are seven distinct stratigraphic zones (numbered from bottom to top) in the Maynardville Limestone near Y-12 (Shevenell 1995). Because of vuggy porosity related to dissolution of gypsum nodules, the uppermost stratigraphic zone (Zone 6) is the most permeable and probably transmits the bulk of the groundwater in the Maynardville Limestone (Goldstrand 1995).

Available data indicated fairly homogeneous groundwater geochemistry in the Maynardville Limestone; almost every monitoring well in this formation, regardless of depth, yields calcium-magnesium-bicarbonate groundwater. Some shallow wells monitor sulfate-enriched groundwater, which probably reflects dissolution of locally disseminated secondary minerals, including gypsum, anhydrite, and pyrite. Also, several deep wells monitor calcium-magnesium-sulfate groundwater with very high total dissolved solids (TDS).

Isopleths of groundwater elevations in the Maynardville Limestone show a low hydrologic divide in BCV near the west end of Y-12, with flow along geologic strike to the west-southwest in the Bear Creek Regime (Figure A.8) and along geologic strike to the east-southeast in the East Fork Regime (Figure A.9). In the Bear Creek Regime, groundwater from the deeper flow system in the Maynardville Limestone discharges along major gaining (influent) reaches of Bear Creek. These discharge areas are possibly related to large-scale structural (e.g., cross-strike faults) or stratigraphic discontinuities in the Maynardville Limestone. Also, in the East Fork Regime, shallow flow in the Maynardville Limestone in the eastern Y-12 area is primarily to the east (along geologic strike) toward Union Valley east of the ORR boundary, but the UEFPC distribution channel underdrain apparently functions as a highly permeable groundwater flow path and a constant head (recharge) boundary that strongly influence local flow directions (BJC 1998). Additionally, operation of the Lake Reality Sump, which is a 6-ft diameter, 20-ft deep sump installed to reduce hydraulic pressure on the synthetic liner in Lake Reality, periodically decreases water levels in the Maynardville Limestone along the main channel of UEFPC. The sump is activated manually as required (very infrequently) to reduce pressure head and stop liner flotation. Once activated, the sump pump operates on an automatic level switch. The last time the sump operated was July 26-27, 2000.

Results of a long-term pumping test and concurrent dye-trace test performed in July 1998 provide the most recent data regarding the hydrologic characteristics of the intermediate and deep groundwater flowpaths in the Maynardville Limestone in the East Fork Regime, and the degree of hydraulic connection between the shallow and deep flow systems in the eastern Y-12 area (BJC 1998). A stepped pump test was performed using a well (GW-845) installed in the Maynardville Limestone about 250 ft southeast of NHP. Groundwater was continuously pumped from the well (which has an open-hole interval from 157 to 438 ft bgs) at progressively increased discharge rates: 25 gallons per minute (gpm) for 24 hours, 50 gpm for 24 hours, and 100 gpm for seven days (pumping started on July 9, 1998 and stopped on July 18, 1998). Water level drawdown and recovery data obtained from nearby monitoring wells indicated: (1) rapid, large responses in wells located along strike to the east and across strike to the north of the pumping well, (2) more moderate responses in wells located oblique to strike near the contact with the Nolichucky Shale to the east of the pumping well, (3) weak responses in upgradient wells in the Maynardville Limestone to the west of the pumping well, and (4) little if any response in wells located adjacent to Lake Reality and the UEFPC distribution channel underdrain to the north and northeast of the pumping well. The maximum observed radius of influence from the pumping well encompassed the entire subcrop of the Maynardville Limestone

in the eastern Y-12 area, with particularly strong anisotropies to the east (along strike) and north (up-dip) of the well and low-permeability boundary effects along the contact with the Nolichucky Shale.

In conjunction with the pumping test, eosine dye was injected in a shallow (60 ft bgs) well (GW-153) located about 450 ft southwest (upgradient) of the pumping well (GW-845). Rapid breakthrough of the dye observed in the pumping well clearly demonstrated the hydraulic connection between the shallow and intermediate/deep groundwater flowpaths along strike in the Maynardville Limestone. Additionally, confirmed detection of the dye in two shallow wells (GW-220 and GW-832) located about 600 ft northeast (across geologic strike) of the injection well (and about 300 ft northwest of the pumping well) suggests that the degree of hydrologic connection with the UEFPC distribution channel underdrain and groundwater movement along dip parallel or conjugate fracture flowpaths in the shallow flow system are strong enough to overcome the hydraulic capture zone created at the 100 gpm pumping rate in the intermediate to deep flow systems (BJC 1998).

Based on the information obtained from the long-term pumping test and associated dye trace, well GW-845 was designated as the groundwater extraction point for the contaminant plume capture system required under an interim action ROD for Union Valley (DOE 1997b). Full operation of the system began in October 2000 and has involved pumping well GW-845 at a rate of 25 gpm and treating the groundwater to remove particulates, iron, manganese, and volatile organic compounds (VOCs). Monthly water level measurements in selected observation wells show that continuous operation of the system has generally maintained 15 to 17 ft of drawdown in the immediate vicinity of well GW-845 and has established an elongated zone of influence that extends parallel with geologic strike for at least 900 ft to the east (downgradient) and 600 ft to the west (upgradient) of the pumping well (DOE 2002).

2.4.1.2 Knox Group

The Knox Group formations underlying Chestnut Ridge comprise three vertically gradational hydrogeologic subsystems: (1) the stormflow zone, (2) the vadose zone, and (3) the groundwater zone. The subsystems are distinguished by groundwater flux, which decreases with depth (Solomon, et. al. 1992).

Investigations on Chestnut Ridge in a watershed located approximately 4,000 ft west of the Chestnut Ridge Regime show that groundwater occurs intermittently above the water table in a shallow "stormflow zone" that extends to a depth of about 8 ft bgs (Wilson et al. 1990). Macropores and mesopores provide the primary channels for lateral flow in the stormflow zone, which lasts only a few days (5 - 10) after rainfall. Most groundwater within the stormflow zone is either lost to evapotranspiration or recharge to the water table, and the remaining water discharges at nearby seeps, springs, or streams (Moore 1989a).

The vadose zone occurs between the stormflow zone and the water table, which typically occurs near the bedrock/residuum interface. Soil moisture content in the vadose zone is below the saturation limit except in the capillary fringe above the water table and within wetting fronts during periods of vertical percolation from the stormflow zone (Moore 1989a). Most recharge through the vadose zone is episodic and occurs along discrete permeable fractures that become saturated, although surrounding micropores remain unsaturated (Solomon, et. al. 1992). The residuum is hydrologically heterogeneous, with quickflow via dolines to conduits in the subsurface; residuum on Chestnut Ridge near the Oak Ridge National Laboratory (ORNL) has a mean hydraulic conductivity of about 0.006 feet per day (ft/d) (Moore 1988a).

Groundwater below the vadose zone occurs within orthogonal sets of permeable, planar fractures that form water-producing zones within an essentially impermeable matrix. Dissolution of bedrock carbonates has enlarged fractures and produced an interconnected conduit-flow system characteristic of karst aquifers. Because the occurrence of solution features and the frequency, aperture, and connectivity of permeable fractures decrease with depth, the bulk hydraulic conductivity of the groundwater zone is vertically gradational. Most groundwater flux occurs within the transitional horizon between residuum and unweathered bedrock (water table interval); lower flux (and longer solute residence times) occurs at successively greater depths in the bedrock (Solomon, et. al. 1992).

Available data show that hydraulic conductivity in the Knox Group varies over multiple orders of magnitude, which is typical of karst aquifers. Results of straddle packer tests in core holes indicate hydraulic conductivity ranging from 0.0002 to 3.1 ft/d at depths generally less than 600 ft bgs in the lower Knox Group (King and Haase 1988). Hydraulic conductivity values calculated from results of falling-head slug tests performed in monitoring wells completed at shallow depths (60 to 195 ft bgs) in the middle Knox Group range from about 0.003 to 14 ft/d (Jones 1998). Also, results of a preliminary dye-tracer test at the Chestnut Ridge Security Pits (CRSP) indicate flow rates of about 100 to 300 ft/d (MMES 1990). Although not confirmed by a second test using different tracers (MMES 1993), these findings are supported by the range of flow rates (490 to 1,250 ft/d) indicated by results of a dye-tracer test performed on Chestnut Ridge near ORNL (Ketelle and Huff 1984).

Groundwater elevations on Chestnut Ridge generally mirror surface topography (Figure A.10). Along the crest of the ridge, which is a recharge area and a flow divide, groundwater generally flows from west to east (parallel to geologic strike), with radial components of flow north into BCV and south toward tributary headwaters on the southern flank of the ridge (across geologic strike). The central part of the regime is characterized by radial flow directions from local groundwater flow divides along hilltops between tributaries. Groundwater flow directions in the southern part of the regime are generally south toward Melton Hill Reservoir. The overall directions of groundwater flow throughout the Chestnut Ridge Regime do not significantly change during seasonal groundwater flow conditions. Horizontal hydraulic gradients throughout the year are highest along the steep northern flank of Chestnut Ridge (i.e., across geologic strike) and in the upper reaches of tributaries on the southern ridge flank, and are nearly flat along the southern boundary of the regime.

Groundwater in the Knox Group has fairly homogeneous geochemistry. Most wells yield calcium-magnesium-bicarbonate groundwater with pH of 7.5 to 8.0; TDS above 150 milligrams per liter (mg/L); equal or nearly equal molar concentrations of calcium and magnesium; low proportions (<5%) of chloride, sodium, sulfate, and potassium; and very low (i.e., <1 mg/L) carbonate alkalinity and nitrate (as N) concentrations. Some wells yield groundwater with enriched chloride and sulfate concentrations that probably reflect the geochemical influence of locally disseminated evaporates (e.g., gypsum) or sulfides (e.g., pyrite). Additionally, groundwater within low permeability (matrix) intervals in the upper Knox Group (e.g., Mascot Dolomite), as indicated by data for several wells at Kerr Hollow Quarry, often exhibits greater proportions of sulfate and potassium and higher trace metal concentrations (e.g., strontium) than typical of the groundwater from low yield intervals within the lower Knox Group formations (e.g., Copper Ridge Dolomite). These geochemical differences potentially reflect corresponding differences between carbonate mineralogies in the upper and lower sections of the Knox Group or the proximity to and types of disseminated secondary minerals (Lockheed Martin Energy Systems, Inc. [LMES] 1996).

2.4.2 Aquitard

The geologic formations that comprise the aquitard directly underlie the primary contaminant source areas in the Bear Creek Regime and the East Fork Regime and are hydraulically upgradient of the Maynardville Limestone throughout much of BCV. Fractures provide the primary groundwater flowpaths in the aquitard; flow through the rock matrix is negligible but nevertheless plays an important role in contaminant migration because of matrix diffusion processes. Flow directions are primarily parallel to bedding (along geologic strike and dip), which may or may not coincide with the direction of maximum horizontal hydraulic gradient inferred from groundwater elevation isopleths. Most flow occurs within the shallow bedrock interval less than 100 ft bgs. Flow across bedding occurs primarily along permeable zones formed by cross-cutting fractures or fracture zones (and possibly small faults). Some of these cross-cutting structures may act as barriers to lateral flow, causing groundwater from deeper intervals to upwell and discharge to the shallower flow system. Others may serve as preferential pathways for migration of contaminants from the aquitard into the Maynardville Limestone.

Most groundwater flow in the aquitard occurs within a highly permeable interval near the bedrock/residuum interface. West of Y-12 in the Bear Creek Regime, flow in the aquitard above the water table occurs in response to precipitation when flowpaths in the residual soils become saturated and rapidly transmit water laterally (stormflow) down slope toward springs, seeps, streams and vertically (recharge) to the water table interval. In the East Fork Regime, however, infiltration into the subsurface and recharge to the water table interval is strongly influenced by the many buildings and other impervious surfaces that cover much of the regime as well as the extensive areas of fill and networks of subsurface storm drains, sewers, and process lines.

Recharge to the water table interval in the aquitard promotes strike-parallel groundwater flow toward nearby discharge areas, which include the subsurface drainage network in the East Fork Regime and the northern tributaries of Bear Creek in the Bear Creek Regime. Although the presence of contaminants in groundwater more than 200 ft bgs in the Nolichucky Shale clearly indicates permeable flowpaths at depth, flow is most active at depths less than 100 ft bgs, and only a small percentage of total flow ultimately recharges the deeper bedrock, where upward hydraulic gradients predominate. In the Bear Creek Regime, about 94% of the available groundwater in the aquitard discharges to Bear Creek tributaries, about 5% flows along cross-cutting fractures into the aquifer, and about 1% flows through strike-parallel pathways in the deeper subsurface (DOE 1997a).

Decreasing groundwater flux with depth in the aquitard in BCV also is reflected by distinct changes in groundwater geochemistry. Most water table interval and shallow (i.e., <100 ft bgs) bedrock wells monitor calcium-magnesium-bicarbonate groundwater. A fairly abrupt change to sodium-bicarbonate groundwater, which is interpreted to be a function of longer groundwater residence time related to reduced fracture aperture or increased fracture spacing (Solomon, et. al. 1992), occurs at a depth of about 100 ft bgs. Further reduced groundwater flux is indicated by the transition from sodium-bicarbonate groundwater to sodium-chloride groundwater that usually occurs at a depth of about 400 ft bgs. The transition to the sodium-chloride groundwater is accompanied by a general increase in TDS.

Isopleths of seasonal groundwater surface elevations in the aquitard (water table interval) in the Bear Creek Regime (Figure A.8) and East Fork Regime (Figure A.9) indicate flow to the west-southwest and east-southeasterly, respectively, toward the Maynardville Limestone. In the East Fork Regime, however, the operation of basement dewatering sumps and the network of subsurface storm drains and utilities throughout much of the western and central Y-12 areas (Figure A.7) strongly influences the movement and discharge of

shallow groundwater. For instance, operation of sumps to suppress the local water table below the basement floor of Buildings 9204-4, 9201-5, and 9201-4, and possibly 9204-2 strongly influences local groundwater flow and contaminant transport patterns (DOE 1998).

2.5 GROUNDWATER CONTAMINATION

Groundwater quality monitoring data obtained from the extensive network of monitoring wells associated with Y-12 show that the most widespread groundwater contaminants are nitrate, VOCs, uranium isotopes (primarily uranium-234 [U-234] and uranium-238 [U-238]), and technetium-99 (Tc-99). Maps illustrating the generalized extent of nitrate, VOCs, uranium isotopes (as indicated by gross alpha radioactivity), and Tc-99 (as indicated by gross beta radioactivity) are provided on Figures A.11, A.12, A.13, and A.14, respectively. The following sections provide an overview of groundwater contamination in the Bear Creek Regime, East Fork Regime, and Chestnut Ridge Regime.

2.5.1 Bear Creek Regime

The following sections briefly describe the primary sources of groundwater contamination in the Bear Creek Regime (the S-3 Site, the Oil Landfarm waste management area [WMA], and the Bear Creek Burial Grounds [BCBG] WMA) and the principal groundwater transport pathway in the regime (the Maynardville Limestone).

2.5.1.1 S-3 Site

Operation of the former S-3 Ponds emplaced a large reservoir of contamination in the aquitard (Nolichucky Shale) consisting of a heterogeneous mix of inorganic, organic, and radioactive constituents. The principal contaminants are nitrate, Tc-99, uranium isotopes, trace metals (e.g., cadmium), and VOCs. Contaminant concentrations in the aquitard nearest the site have probably reached maximum levels, with the center of mass of the plume slowly moving westward. Westward, strike parallel migration of contaminants in the aquitard occurs until encountering a cross-cutting structure that promotes upward discharge into the shallow flow system or cross-strike flow into the Maynardville Limestone (DOE 1997a). Additionally, matrix diffusion and advective transport processes are slowly releasing contaminants (e.g., nitrate) from the deeper reservoir into the more active (shallow) aquitard flow system.

In the aquitard, nitrate from the former S-3 Ponds extends directly south in the water table interval into the upper reach of Bear Creek and along strike in the water table interval and the deeper bedrock for over 3,000 ft to the west. Because it is highly mobile and chemically stable, nitrate delineates the maximum extent of groundwater transport from the S-3 Site and effectively traces the principal migration pathways in the aquitard. Nitrate (as N) concentrations (hereafter synonymous with "nitrate" concentrations) within the plume exceed 10,000 mg/L in the deep bedrock directly below the S-3 Site, 1,000 mg/L in the shallow groundwater near the site, and 10 mg/L near the plume boundaries.

Gross alpha activity and gross beta activity within the S-3 Site contaminant plume exceed 1,000 picoCuries per liter (pCi/L). Although a diverse population of radioisotopes is present in the groundwater closest to the site, elevated gross alpha and gross beta activity in the groundwater probably delineate migration of uranium isotopes (U-234 and U-238) and Tc-99, respectively, since these were the dominant radiological constituents

in wastes placed into the former S-3 Ponds. Also, sludge produced by denitrification of the waste water in each pond was left in place after closure of the site. Sludge within the saturated zone may release Tc-99 and uranium isotopes to the shallow groundwater flow system in the aquitard (DOE 1997a). These contaminants then may be transported southward towards Bear Creek and westward through the water table interval toward discharge points in NT-1 (DOE 1997a).

Other components of the S-3 Site contaminant plume are trace metals and VOCs. The distribution of trace metals is less extensive than that of nitrate and radioactivity, but the most mobile metals within the plume (e.g., barium) have been transported beyond the acidic groundwater (pH <5) nearest the site. Acetone and tetrachloroethene (PCE) are the principal VOCs within the plume. Concentrations of PCE exceed 5,000 micrograms per liter (μ g/L) in wells adjacent to the site, potentially indicating the presence of dense nonaqueous phase liquids (DNAPL) in the subsurface, but decrease to less than 50 μ g/L about 500 ft downgradient of the site. This reflects the limited extent of PCE migration and suggests substantial natural attenuation in the subsurface.

2.5.1.2 Oil Landfarm WMA

The primary sources of groundwater contaminants in the Oil Landfarm WMA are the Boneyard/Burnyard, the Hazardous Chemical Disposal Area (HCDA), the Oil Landfarm disposal plots, and Sanitary Landfill I. Each of these sites except the Boneyard/Burnyard is a known or suspected source of VOCs in the shallow groundwater; the Boneyard/Burnyard is a major source of elemental uranium and alpha radioactivity in the Bear Creek Regime.

The Boneyard was used for the disposal of magnesium chips and construction debris (e.g., concrete) in unlined shallow trenches. Filled trenches were covered with topsoil and seeded with grass. The Burnyard consisted of two unlined trenches, each about 300 ft long by 40 ft wide, in which various types of refuse (including pesticide containers, metal shavings, solvents, oils, and laboratory chemicals) were burned. Some residues may have been buried in the Boneyard. Because the Boneyard/Burnyard is a primary source of uranium in the groundwater and surface water in BCV (DOE 1997a), this site was prioritized for CERCLA remedial action, which was performed in three phases. Remedial designs for the site were prepared during Phase I and remedial action field work began with Phase II. Completed in November 2001, Phase II primarily involved construction of an upgradient subsurface drain to hydraulically isolate the buried wastes at the site in order to reduce the flux of contaminants from the site and to dry the site in preparation of the Phase III field work, which began in May 2002. Phase III focused on the excavation, disposal, and consolidation of wastes from the site and the reconstruction of a section of NT-3 that drains the site. Waste removal actions were completed in October 2002 and involved the excavation of about 64,000 cubic yards (yd³) of waste materials with the highest concentrations of uranium that were in contact with groundwater. These wastes were disposed in the EMWMF. About 17,000 yd³ of other waste materials that had lower levels of uranium contamination and were not in contact with groundwater also were excavated, consolidated onsite, and covered with a low-permeability recompacted clay cap. Installation of the cap, including seeding/mulching the topsoil cover, was completed in November 2002. Field work to restore the NT-3 stream channel with natural meanders and gradients in order to reduce erosion of the bank and more efficiently transport water and sediment load through the site is currently scheduled for completion in May 2003 (BJC 2003a).

The HCDA was constructed on top of the Burnyard in 1975 and was used as an area for releasing compressed gas from cylinders with leaking or damaged valves and for disposal of reactive or explosive laboratory chemicals. The chemicals were handled to induce the expected reaction or explosion, and remaining liquids

were discharged into a small unlined surface impoundment. A low permeability cap was constructed over the HCDA during closure of the Oil Landfarm. In June 2002, a section of the northwest corner of the cap was excavated and removed during Phase III of the CERCLA remedial action at the Boneyard/Burnyard. Excavated wastes were replaced with uncontaminated soil and the filled area was graded to drain, mulched, and seeded with grass (BJC 2003a).

Groundwater contaminants at the Oil Landfarm are principally VOCs, and a commingled plume containing two distinct suites of VOCs are evident: one to the northeast dominated by 1,1,1-trichloroethane (111TCA), 1,1-dichloroethane (11DCA), and 1,1-dichloroethene (11DCE); and one to the south dominated by PCE, cis-1,2-dichloroethene (c12DCE), trans-1,2-dichloroethene (t12DCE), and trichloroethene (TCE) (MMES 1989). The dissolved VOC plume appears to be restricted to the shallow flow system. Summed VOC concentrations exceed 1,000 μ g/L in the northeast part of the plume and 100 μ g/L in the southern part of the plume; maximum concentrations within the plume do not indicate the presence of DNAPL in the subsurface.

Sanitary Landfill I is a probable source of 11DCA, c12DCE, and t12DCE in the shallow groundwater (aquitard and aquifer) downgradient to the south of the site. Maximum VOC concentrations are typically less than 50 μ g/L. In the Maynardville Limestone, these constituents have intermingled with the VOC plume (primarily TCE and c12DCE) originating from upgradient sources. Sanitary Landfill I also may be a source of boron in the groundwater at several wells immediately downgradient (west) of the site.

2.5.1.3 Bear Creek Burial Grounds WMA

Groundwater in the aquitard underlying the BCBG WMA is extensively contaminated with VOCs at both shallow (water table) and deep (bedrock) intervals. There are five primary source areas: Burial Ground (BG)-A (North and South), BG-C (East and West), and the Walk-In Pits (Figure A-12). Dissolved VOC plumes in the shallow groundwater at several of these source areas are probably related to widespread occurrence of DNAPL in the subsurface. Contamination in the deeper groundwater flow system reflects density-driven, downward migration of DNAPL.

The disposal trenches comprising BG-A (North and South) received almost two million gallons of waste oils and coolants, and DNAPL has been encountered at 260 ft and 330 ft bgs in monitoring wells downdip of source trenches in BG-A South (MMES 1990b). Dissolved VOC plumes in the groundwater underlying both areas are dominated by PCE, TCE, and c12DCE. Other common plume constituents are 111TCA, 11DCA, and 1,2-dichloroethane (12DCA). Summed concentrations of these plume constituents exceed $100,000\,\mu\text{g/L}$. Groundwater in the water table interval transports the plume constituents along strike toward discharge areas in NT-7. Strike-parallel migration also occurs below the water table interval, as reflected by westward (strike-parallel) transport of PCE indicated by data obtained from deeper bedrock wells west of BG-A South.

Separate plumes of dissolved VOCs apparently occur in the shallow groundwater at BG-C East and BG-C West, each plume dominated by c12DCE with lesser amounts of vinyl chloride (VC), both of which are degradation products of PCE. The concentrations of VOCs in each plume are generally less than 500 μ g/L. Groundwater containing these VOCs discharges to the NT-8 catchment on the northwest side of the Burial Grounds WMA. Data for both source areas do not clearly indicate the presence of DNAPL in the subsurface (DOE 1997a).

Groundwater near the Walk-In Pits contains a distinct plume of dissolved VOCs dominated by PCE. Concentrations exceed 2,000 µg/L, which is about 1% of the maximum PCE solubility and possibly indicates DNAPL in the subsurface. Contaminants in the shallow groundwater flow system near the Walk-In Pits may not discharge extensively to surface water (DOE 1997a).

Although large quantities of uranium wastes were disposed in the BCBG WMA, few monitoring wells in the area yield radioactive groundwater samples. However, data for soil samples and surface water samples collected from NT-6, NT-7, and NT-8 indicate that uranium isotopes from BG-A South and BG-C East are probable sources of elevated alpha and beta radioactivity (DOE 1997a). Maximum gross alpha and gross beta activities in the samples from these tributaries ranged from about 20 pCi/L to more than 100 pCi/L. The disparity with the groundwater sample data may be an artifact of the monitoring well network (few wells are screened within the shallowest water table interval where radioactive contamination likely occurs), but the relatively low levels of radioactivity in the groundwater also suggest that the bulk of the uranium wastes in BG-A South and BG-C East are not within the saturated zone (DOE 1997a).

Boron is the primary trace metal contaminant in the groundwater at the BCBG WMA. Elevated boron concentrations occur primarily in the shallow groundwater near BG-A South and BG-C (East and West) and probably resulted from disposal of borax wastewater from Y-12. Boron is most likely present in the groundwater as borate [B(OH)₃], which is chemically stable and relatively mobile, and is transported toward discharge points in Bear Creek tributaries NT-7 and NT-8.

2.5.1.4 Maynardville Limestone Exit Pathway

Groundwater contaminants in the Maynardville Limestone originate from the S-3 Site (nitrate and Tc-99), the Boneyard/Burnyard (uranium isotopes), Sanitary Landfill I (VOCs), the BCBG WMA (VOCs and uranium isotopes), and the Rust Spoil Area (VOCs) or an unidentified source area in the Bear Creek floodplain adjacent to the Rust Spoil Area. These contaminants enter the Maynardville Limestone through direct recharge, hydrologic communication with surface water in Bear Creek, and inflow of shallow groundwater from the aquitard. Relative contributions from the source areas and the geochemical characteristics of the contaminants have produced two primary plumes of contamination in the groundwater, one containing nitrate and radioactivity and another containing VOCs. Both plumes occur in the shallow karst network and the deeper fracture flowpaths and are commingled downgradient of the Boneyard/Burnyard.

The nitrate plume (Figure A-11) in the aquifer essentially delineates the maximum extent of contaminant transport from the former S-3 Ponds and effectively traces the principal migration pathways in the Maynardville Limestone. The plume is continuous in the deeper bedrock from south of the S-3 Site for about 10,000 ft along strike to the west, whereas attenuation from more active recharge and groundwater flux has reduced nitrate levels and produced a more discontinuous nitrate plume in the shallow karst network. Nitrate concentrations within the plume exceed 500 mg/L south of the S-3 Site, but rapidly decrease to less than 50 mg/L south of the Oil Landfarm WMA, and are typically highest in the fracture-dominated groundwater flow system at depths greater than 100 ft bgs.

The distribution of VOCs (Figure A-12) in the Maynardville Limestone reflects the relative contributions of several source areas and commingling during downgradient transport. Plume constituents in the upper part of BCV are TCE, c12DCE, and PCE; probable source areas are Spoil Area I, the S-3 Site, and possibly the Fire Training Facility in the East Fork Regime. The major inputs to the plume occur from the Rust Spoil Area

(TCE) or a nearby source in the Bear Creek floodplain, the HCDA (TCE and c12DCE), Sanitary Landfill I (111TCA and 11DCA), and discharge from the Bear Creek tributary (NT-7) that traverses BG-A North and A South (c12DCE and 12DCA). The highest concentrations within the plume (i.e., $>300~\mu g/L$) occur in the deeper groundwater south (down dip) of the HCDA. These high concentrations coincide with the downward vertical hydraulic gradients in the Maynardville Limestone in this area and the major losing reach of middle Bear Creek south of Sanitary Landfill I.

Radioactivity in the groundwater in the Maynardville Limestone is primarily from uranium isotopes and Tc-99. The extent of these radionuclides are generally delineated by gross alpha activity (Figure A.13) and gross beta activity (Figure A.14), respectively. The distribution of gross beta activity mirrors that of nitrate, indicating both a common source of nitrate and Tc-99 (the S-3 Site) and migration along common flowpaths. Increased gross alpha activity in the groundwater downstream of the NT-3 catchment reflects inputs of uranium isotopes from former sources in the Boneyard/Burnyard. Before their excavation and removal in May 2002 (see Sect. 2.5.1.2), waste materials containing high concentrations of uranium were within the saturated zone during seasonally high groundwater levels. Uranium isotopes that were leached from the wastes were transported with the shallow groundwater that discharges into NT-3 and recharges directly into the Maynardville Limestone. Prior to the removal of the wastes, gross alpha and gross beta activity exceeded 1,000 pCi/L in the shallow groundwater along NT-3 from the northwest corner of the site to the confluence of NT-3 and Bear Creek (Figure A.13).

Most trace metal contamination in the Maynardville Limestone occurs in the shallow groundwater near the S-3 Site and the Boneyard/Burnyard. Near the S-3 Site, the principal trace metal contaminants are barium, boron, cadmium, copper, lead, mercury, strontium, and uranium. Some of these metals (e.g., cadmium) were entrained in the highly acidic wastes disposed at the site, and others (e.g., barium and strontium) were dissolved from the underlying bedrock. Trace metal contamination is sporadic in the groundwater at the Boneyard/Burnyard and the principal contaminants are beryllium, manganese, mercury, nickel, and uranium. Boron and uranium are the most common trace metal contaminants in the aquifer downgradient of the S-3 Site and the Boneyard/Burnyard, which indicates that relatively mobile ionic species of both metals are present in the groundwater.

2.5.2 East Fork Regime

Sources of groundwater contamination in the East Fork Regime include hazardous and nonhazardous waste treatment, storage, or disposal sites; bulk product transfer, storage, and use areas; former petroleum-fuel underground storage tanks (USTs) and associated dispensing facilities; industrial process buildings; waste and product spill areas; and the many process pipelines, effluent drains, and utilities associated with the industrial operations at Y-12. Also, operation of the former S-3 Ponds emplaced a large reservoir of contamination in the western Y-12 area. Intermingling of contaminants from multiple source areas has produced an extensive, essentially continuous groundwater contaminant plume of varying composition that extends from the western Y-12 area through the southern part of the central and eastern Y-12 areas and into Union Valley east of the ORR (Figure A.12).

A plume of nitrate contamination originating from the former S-3 Ponds extends vertically in the aquitard at least 150 ft bgs and laterally at least 5,000 ft into the western Y-12 area. Nitrate concentrations within the plume exceed 10,000 mg/L. The geometry of the nitrate plume indicates two principal migration pathways: (1) relatively rapid migration along fairly short, shallow pathways (<30 ft bgs) that typically terminate in storm drains or other utilities, building sumps, and the buried tributaries and original mainstream of UEFPC;

and (2) substantially slower migration along much longer strike-parallel pathways at greater depths in the bedrock toward basement sumps in Buildings 9204-4, 9201-4, and 9201-5 (DOE 1998). The S-2 Site also is a minor source of nitrate.

The low pH groundwater within the contaminant plume originating from the former S-3 Ponds contains a diverse mix of metal ions and/or ion-complexes (beryllium, cadmium, cobalt, manganese, mercury, and nickel) that are usually not mobile (or are more readily attenuated) in less acidic groundwater, as well as metals that are mobile under a wider range of groundwater pH conditions (barium, boron, strontium, and uranium). Some of these metals were entrained in the acidic wastes disposed at the site (e.g., uranium), and others were dissolved from the underlying saprolite and bedrock (e.g., barium and strontium). Concentrations of several trace metals (e.g., barium) within the plume exceed the applicable Safe Drinking Water Act (SDWA) maximum contaminant level (MCL) for drinking water by an order-of-magnitude or more. Similarly elevated concentrations of several other trace metals (including boron, cadmium, cobalt, copper, mercury, and uranium) occur in the groundwater elsewhere in the East Fork Regime, notably the S-2 Site, but available data do not indicate that extensive plumes of metal ions and/or ion-complexes have developed in the groundwater beyond the immediate vicinity of these sites.

Volatile organic compounds are the most pervasive groundwater contaminants in the East Fork Regime. The principal components of dissolved VOC plumes in the western Y-12 area and the central Y-12 area are PCE, TCE, c12DCE, 11DCE, and VC. Chloroethanes (primarily 111TCA and 11DCA) are also major components of several plumes in the central Y-12 area. In the eastern Y-12 area, dissolved chloromethanes, primarily carbon tetrachloride (CTET), chloroform, and methylene chloride (MC) are primary components of the VOC plume. Additionally, residual plumes of dissolved petroleum hydrocarbons (benzene, ethylbenzene, dimethylbenzene, and toluene) occur in shallow groundwater near former petroleum fuel USTs. In the aquitard, concentrations of individual plume constituents exceed 1,000 µg/L in the shallow groundwater near the Waste Coolant Processing Area (WCPA), Building 9212, and Tank 0134-U and indicate the presence of DNAPL in the subsurface. At shallow depths (<100 ft bgs) in the Maynardville Limestone, a relatively continuous plume of dissolved VOCs begins near the Fire Training Facility in the western Y-12 area, intermingles with VOC plumes from several sources in the central Y-12 area, and extends underneath NHP in the eastern Y-12 area. The extent of the plume at intermediate (>200 ft bgs) and deep (>400 ft bgs) intervals in the Maynardville Limestone is not well defined in the western and central Y-12 areas because of limited well coverage. However, data from the network of wells in the eastern Y-12 area show that a plume of dissolved chloromethanes (primarily CTET), which is believed to originate from suspected DNAPL in the Maynardville Limestone west of NHP near Building 9720-6, extends vertically more than 400 ft bgs and laterally (parallel with geologic strike) into Union Valley at least 2,000 ft east of the ORR boundary.

Groundwater with radiological contamination occurs primarily in the aquitard east of the former S-3 Ponds, at Tank 0134-U, Buildings 9204-4 and 9201-5, and the Salvage Yard. In the Maynardville Limestone, radiological contamination occurs near the S-2 Site and upgradient of NHP (the Uranium Oxide Vault, wells GW-605 and GW-606, and the former Oil Skimmer Basin). The former S-3 Ponds are the principal source of uranium isotopes (primarily U-234 and U-238) and Tc-99; the migration of Tc-99 generally mirrors that of nitrate from the site. Gross alpha radioactivity levels within the plume exceed the 15 pCi/L MCL and gross beta radioactivity levels within the plume exceed the SDWA screening level (50 pCi/L) for a 4 millirem per year (mrem/yr) dose equivalent (the drinking water MCL for gross beta radioactivity). Relatively limited influx of radiological contamination directly into the aquifer (or extensive dilution) in the East Fork Regime is indicated by the greatly decreased gross alpha, gross beta, and isotopic uranium activity in the groundwater downgradient of known source areas (e.g., S-2 Site and the former Oil Skimmer Basin).

2.5.3 Chestnut Ridge Regime

Groundwater contamination is much less extensive in the Chestnut Ridge Regime and VOCs are the most common groundwater contaminants (Figure A.12). Dissolved VOCs (primarily chloroethanes and chloroethenes) have been detected in the groundwater samples collected from monitoring wells downgradient from the CRSP and Industrial Landfill IV. However, a clearly distinct plume of dissolved VOCs is indicated only by the data for wells at the CRSP.

The CRSP are located on the crest of Chestnut Ridge directly south of the central portion of Y-12, and consist of two areas containing a series of east-west oriented trenches that are about 8 to 10 ft wide, 10 to 18 ft deep, and 700 to 800 ft long. Beginning in 1973, the trenches received hazardous wastes until December 1984 and nonhazardous wastes until the site was closed in November 1988. Data obtained from monitoring wells at the site indicate that a narrow, elongated plume of dissolved VOCs extends parallel with geologic strike for at least 2,600 ft downgradient to the east, and perpendicular to geologic strike for at least 500 ft downgradient to the north and south. The primary components of the plume include 111TCA, 11DCA, and 11DCE near the western trench area, and PCE, TCE, and 1,2-dichloroethene (12DCE) isomers near the eastern trench area. The distribution of the dissolved plume constituents relative to the respective source areas and elongation of the plume along the axis of Chestnut Ridge, despite steeper hydraulic gradients toward the ridge flanks, suggest primarily strike-parallel horizontal transport (west to east) in the groundwater (and possibly vapor phase transport). The maximum depth of vertical migration of the VOCs has not been conclusively determined, but is at least 150 ft bgs in the western trench area, 250 ft bgs near the middle of the site, and 270 ft bgs downgradient of the eastern trench area.

Data obtained since the early 1990s show that low concentrations (many are estimated values below analytical reporting limits) of one or more VOCs (primarily 111TCA) are present in the groundwater at two wells hydraulically downgradient of the waste disposal trenches at the CRSP: well GW-796, which is located at Industrial Landfill V about 400 ft directly south of the site, and well GW-798, which is located at Construction Demolition Landfill VII about 1,600 ft south-southeast of the site (Figure A.12). Subsequent monitoring results indicate that VOC levels in both wells remain relatively low, with the more recent data showing that PCE concentrations in well GW-798 occasionally exceed the MCL (5 μ g/L). The repeated detection of these compounds in the groundwater at both wells probably reflects southward transport from the CRSP because this site is the only known source of VOCs that is hydraulically upgradient of either well.

Industrial Landfill IV, which is located on the crest of Chestnut Ridge directly south of the west end of Y-12, has received non-hazardous solid waste since October 1989 and is a suspected source of 111TCA, 11DCA, 11DCE, and boron in the groundwater downgradient of the site. Elevated total boron concentrations occur in a well located downgradient to the east of the site (GW-217), while VOCs have been repeatedly detected in a well located south of the eastern portion of the site (GW-305). These results potentially indicate groundwater transport along permeable flowpaths from the unlined portion (about 150 ft X 150 ft) at the eastern end of Industrial Landfill IV. Although the source of these contaminants has not been formally confirmed, no other waste management facility is located upgradient of these wells.

Kerr Hollow Quarry is on the broad southern flank of Chestnut Ridge about 1,000 ft north of Bethel Valley Road and served as a source of stone construction material until it filled with water and was abandoned in the late 1940's. From the early 1950s until November 1988, the quarry was used for the disposal of reactive materials from Y-12 and ORNL. Wastes were removed from the quarry between mid-1990 and late 1993 to obtain certified clean-closure status from the TDEC, but the site was finally closed with some wastes remaining in place. Low levels ($<5 \,\mu g/L$) of several VOCs, primarily carbon tetrachloride, chloroform, and

PCE, occur in the groundwater at monitoring wells located to the south (GW-144) and southeast (GW-142) of Kerr Hollow Quarry. Each of these VOCs may be present at low concentrations in the groundwater downgradient of the site, possibly as a consequence of wastes being disturbed during attempts to obtain clean closure of the site, but none of the compounds have been detected in the RCRA wells at the site since 1997.

3.0 SURVEILLANCE MONITORING DATA EVALUATION

This section contains an evaluation of groundwater quality in areas that are, or could be, affected by Y-12 operations. Separate evaluations are provided for the Bear Creek, East Fork, and Chestnut Ridge hydrogeologic regimes based on the CY 2002 monitoring results for a selected network of monitoring wells in each regime. Evaluation of these monitoring results primarily focused on the principal groundwater contaminants at Y-12, as defined by: (1) nitrate concentrations that exceed the 10 mg/L MCL for drinking water; (2) total uranium concentrations that exceed the MCL (0.03 mg/L); (3) individual VOC concentrations that exceed MCLs or summed VOC concentrations that exceed 5 µg/L; (4) gross alpha activity above the MCL (15 pCi/L); and (5) gross beta radioactivity above the SDWA screening level (50 pCi/L) for a 4 mrem/yr dose equivalent (the MCL for gross beta activity).

Analytical results obtained during CY 2002 for the principal groundwater contaminants were evaluated with respect to historical data obtained for each applicable well since January 1991, which coincides with the availability of certain quality assurance/quality control data (e.g., blank sample results) needed to evaluate compliance with the data quality objectives (DQOs) of the Y-12 GWPP, as defined in the *Y-12 Plant Groundwater Protection Program Data Management Plan* (LMES 2000). Historical and CY 2002 analytical results for the principal groundwater contaminants that do not meet applicable DQOs were excluded from quantitative evaluation.

The historical data for most of the wells in each hydrogeologic regime that were sampled during CY 2002 span a major change in the groundwater sampling method used by Y-12 GWPP. A "conventional" sampling method, which was used between January 1991 and September 1997, involved purging (1-2 gpm) a fixed volume of groundwater from a well (or purging the well dry) prior to collecting samples from the well. A "low-flow" sampling method, which has been used since October 1997, involves pumping a well at a flow rate low enough (<300 milliliters per minute) to minimize drawdown of the water column above the screened or open-hole interval in the well. Once drawdown has been minimized and field parameters have stabilized, representative groundwater samples are obtained without inclusion of water in the well casing. Analytical results for the majority of wells in each regime do not exhibit any distinct response to the change in the sampling method. However, results of a detailed quantitative comparison indicate that the conventional sampling and low-flow sampling results for some wells exhibit distinct differences (BWXT 2002). As shown below in Table 4, several of the wells that show such differences were sampled during CY 2002.

Table 4. CY 2002 surveillance monitoring wells with significant differences between conventional sampling and low-flow sampling results for the principal groundwater contaminants

		Principal Groundwater Contaminants							
Well Location/Number			Uranium			C	G		
		Nitrate		Chloro- ethenes	Chloro- ethanes	Chloro- methanes	Petroleum Hydrocarbons	Gross Alpha	Gross Beta
Bear Creek	GW-082			L	L		L		
Regime	GW-225	C		X					
	GW-226	L		L					
	GW-627			L	L				
	GW-653			L	L				
	GW-706	L	X	X				X	X
	GW-725	C		C					

Table 4 (continued)

		Principal Groundwater Contaminants							
Well Location/Number		Nitrate	Uranium	VOCs				~	~
				Chloro- ethenes	Chloro- ethanes	Chloro- methanes	Petroleum Hydrocarbons	Gross Alpha	Gross Beta
East Fork Regime	GW-204 GW-382 GW-605 GW-633	C	C C	C X L		X C X	L	X X	L
	GW-763 GW-782 GW-791	•	•	C X C	X	•		L	•
Chestnut Ridge Regime	GW-205								L

Note: "." = Not a contaminant in the groundwater at the well during CY 2002.

X = No significant difference between concentrations indicated by conventional sampling and low-flow sampling results.

C = Conventional sampling results show significantly higher concentrations than low-flow sampling results.

L = Low-flow sampling results show significantly higher concentrations than conventional sampling

Because of the apparent sensitivity to the groundwater sampling method, evaluation of the monitoring results for these wells is based on separate analysis of the conventional sampling and low-flow sampling data; monitoring results for all other wells that were sampled during CY 2002 were evaluated without regard to the groundwater sampling method.

3.1 BEAR CREEK REGIME

The CY 2002 monitoring results reported for a total of 63 monitoring wells in the Bear Creek Regime were evaluated to meet the surveillance monitoring requirements of DOE Order 5400.1 (Table B.1). As shown on Figure A.2, 40 of the wells are completed in the geologic formations comprising the aquitard (Nolichucky Shale, Maryville Limestone, Rogersville Shale, Pumpkin Valley Shale, and Rome Formation) and 23 of the wells are completed in the geologic formations comprising the aquifer (Copper Ridge Dolomite and Maynardville Limestone). Respective evaluations of the monitoring data for the aquitard wells and aquifer wells are provided in the following sections.

3.1.1 Aguitard Monitoring Wells

As shown below in Table 5, elevated concentrations of one or more of the principal groundwater contaminants in the Bear Creek Regime were reported for at least one of the groundwater samples collected during CY 2002 from 18 of the surveillance monitoring wells completed in the geologic formations that comprise the aquitard.

Table 5. Bear Creek Regime CY 2002: principal groundwater contaminants detected in surveillance monitoring aquitard wells

Well	Monitored	Inor	ganics	Woo	Radioa	ectivity
Number	Interval Depth (ft bgs)	Nitrate	Uranium	VOCs	Alpha Activity	Beta Activity
GW-008	13.0 - 25.5			•		
GW-014	5.0 - 13.2			•		
GW-046	5.0 - 20.3			•		
GW-071	195.1 - 219.0			•		
GW-072	84.5 - 98.4			•		
GW-082	29.4 - 34.4			•		
GW-085	48.4 - 58.8	•				•
GW-087	7.5 - 19.0			•	•	
GW-243	43.2 - 77.0	•	•	•	•	•
GW-276	11.3 - 18.5	•	•	•	•	•
GW-288	46.0 - 60.0			•		
GW-289	28.9 - 40.8			•		
GW-291	9.5 - 17.0			•		
GW-526	101.0 - 123.0	•				
GW-537	4.8 - 23.3	•				•
GW-626	63.0 - 78.0			•		
GW-627	254.0 - 270.0			•	•	
GW-653	26.3 - 39.0			•		
Screen	ning Level	10 mg/L	0.03 mg/L	5 μg/L	15 pCi/L	50 pCi/L

The following sections provide separate discussions of the CY 2002 monitoring results for each major type of contaminant (inorganics, VOCs, and radioactivity).

3.1.1.1 Inorganic Contaminants

As shown below in Table 6, elevated concentrations of nitrate and/or total uranium were reported for at least one groundwater sample collected during CY 2002 from five aquitard monitoring wells (listed in sequence from hydraulically upgradient [north and east] to hydraulically downgradient [south and west]).

Table 6. Bear Creek Regime CY 2002: elevated nitrate and uranium concentrations in surveillance monitoring aquitard wells

		Distance and Direction	Nitrate	(mg/L)	Uraniur	m (mg/L)
Well Location / Nu	ımber	from S-3 Site (Figure A.2)	1st Qtr. 2002	3rd Qtr. 2002	1st Qtr. 2002	3rd Qtr. 2002
S-3 Site	GW-243 GW-276 GW-526	50 ft West 200 ft Southeast 1,300 ft West	7,240 51.3 1,260	8,480 73.7 1,300	0.839 0.723	0.653 0.79
Oil Landfarm WMA	GW-537 GW-085	2,500 ft West 3,000 ft West	669 244	610 233	< <	< .
Note: "." = Not detecte	d; "<" = Le	ess than MCL				

Located adjacent to the west side of the former S-3 Ponds (Figure A.2), well GW-243 is completed in the Nolichucky Shale (shallow bedrock interval) with a monitored interval (43 - 77 ft bgs) that potentially intercepts strike-parallel flowpaths which subcrop directly below the site. Last sampled in March 1994, the historical monitoring data for the well show that it yields very contaminated groundwater containing extremely high concentrations of several inorganic contaminants, some of which (e.g., nitrate and uranium) were entrained in the wastes disposed in the former S-3 Ponds and others (e.g., barium) were dissolved from the bedrock by acidic seepage from the site (DOE 1997a). Monitoring results obtained during CY 2002 show that the well continues to yield highly mineralized groundwater (TDS>50,000 mg/L) and that nitrate concentrations in the well remain above 5,000 mg/L. As shown below in Table 7, the nitrate levels appear to have slightly decreased since the well was last sampled in March 1994, but remain higher than evident during the late 1980s and early 1990s.

Table 7. Selected nitrate and uranium results for well GW-243

		Concentrat	tion (mg/L)	
Analyte	March 1988	March 1992	March 1994	March 2002
Nitrate Total Uranium	4,811 56.6	6,442 36	8,927 30	7,240 0.839

Conversely, (total) uranium concentrations in the well appear to have decreased substantially from the levels evident through the mid-1990s. The data presented in Table 7 show that uranium concentrations decreased about 35% between March 1988 and March 1992, declined another 17% between March 1992 and March 1994, and dropped almost 97% between March 1994 and March 2002. The large proportional decrease in the uranium concentration indicated the CY 2002 monitoring results is probably not directly related to the change from conventional sampling to low-flow sampling because other analytes (e.g., nitrate) do not exhibit similarly large proportional differences between the conventional and low-flow sampling results. The large proportional decrease in the amount of dissolved uranium does coincide with an apparent increase in the pH of the groundwater in the well, as illustrated by the field pH measurements reported for of the groundwater samples collected in March 1988 (4.0), March 1994 (4.0), and March 2002 (5.6). Because pH strongly controls the solubility of uranium in groundwater (Fetter 1993), buffering the acidic groundwater in the shallow flow system near the former S-3 Ponds would be expected to substantially decrease the amount of dissolved uranium in the groundwater at well GW-243 (and other wells located adjacent to the site). However, its is not clear from the available data if inflow of less acidic recharge and/or another hydrochemical process is responsible for the change in the pH of the groundwater in the well.

Well GW-276 yields moderately contaminated, calcium-magnesium-bicarbonate groundwater from the water table interval (<20 ft bgs) in the Nolichucky Shale about 200 ft southeast (across geologic strike) of the former S-3 Ponds (Figure A.2). The CY 2002 monitoring results show that nitrate and uranium concentrations in the well remain substantially above respective MCLs (Table 6). Also, these monitoring data continue the generally decreasing nitrate concentration trend indicated by historical monitoring results (Figure A.15). Decreasing concentrations of nitrate (and other contaminants) in the shallow groundwater at this well are consistent with the conceptual model for contaminant transport from the S-3 Site. This decreasing trend is a consequence of several contributing factors, including reduced flux of nitrate (and other contaminants) following cessation of waste disposal at the former S-3 Ponds, construction of the low-permeability cap during closure of the site, and discharge of contaminated groundwater from the shallow flow system in the aquitard into the surface water drainage system (DOE 1997a). However, a similarly decreasing

concentration trend is not as clearly evident for uranium in the well; uranium levels steadily increased between January 1998 (0.63 mg/L) and July 2000 (0.96 mg/L), peaked sharply at 1.5 mg/L in July 2001, and subsequently dropped below 0.8 mg/L through July 2002 (Figure A.15).

Well GW-526 yields nitrate-contaminated sodium-bicarbonate groundwater from a total depth of 123 ft bgs in the Nolichucky Shale (intermediate bedrock interval) near NT-1, about 1,300 ft west (parallel with geologic strike) of the former S-3 Ponds (Figure A.2). Monitoring results obtained during CY 2002 show that nitrate levels in the well remain above 1,000 mg/L and reflect a fairly indeterminate long-term concentration trend (i.e., not clearly increasing or clearly decreasing over time), as illustrated by the close similarity between the nitrate levels evident in May 1992 (1,102 mg/L) and February 2002 (1,260 mg/L). High concentrations of nitrate (and other contaminants from the former S-3 Ponds) in the shallow subsurface near NT-1 is believed to result from the upwelling of contaminated groundwater from the deeper flow system (DOE 1997a).

The CY 2002 monitoring data show that nitrate concentrations remain above 600 mg/L in the shallow groundwater at well GW-537, which is located near NT-2 about 1,200 ft west (generally parallel with geologic strike) of well GW-526 (Figure A.2). Nitrate concentrations in well GW-537, which is completed at a depth of 23 ft bgs in the Nolichucky Shale (water table interval), are maintained via upward discharge of nitrate from the deeper flow system (DOE 1997a). Upwelling of groundwater from the deeper bedrock also explains the sodium-bicarbonate chemistry of the shallow groundwater in this well. Also, assuming that the center of mass of the nitrate plume in the aquitard is slowly migrating westward (along geologic strike) from the former S-3 Ponds, upwelling of nitrate from the deeper flow system should produce relatively stable or increasing nitrate levels in the shallow groundwater near NT-2 (DOE 1997a). Nitrate results obtained during CY 2002 continue the widely variable, indeterminate long-term concentration trend indicated by the historical monitoring data for well GW-537 (Figure A.15).

Westward strike parallel migration of the contaminant plume emplaced in the aquitard during operation of the former S-3 Ponds also explains the elevated nitrate concentrations in the calcium-magnesium-bicarbonate groundwater at well GW-085, which is completed at a depth of about 59 ft bgs in the Nolichucky Shale (shallow bedrock interval) about 500 ft west of well GW-537 (Figure A.2). Elevated nitrate levels in the groundwater at well GW-085 also show that the leading edge of the nitrate plume in the Nolichucky Shale lies west of the well toward NT-3 (DOE 1997a). Historical monitoring results show that nitrate levels in this well generally increased between May 1991 (115 mg/L) and October 1993 (312.6 mg/L), subsequently decreased to the historical low for the well in March 1998 (43 mg/L), and increased steadily to a peak near 250 mg/L in August 2001 before decreasing slightly though July 2002 (233 mg/L). This trend suggests westward, strike parallel migration of a "pulse" of nitrate in the shallow flow system in the Nolichucky Shale west of the former S-3 Ponds (see Section 5.1).

3.1.1.2 Volatile Organic Compounds

Groundwater samples collected during CY 2002 from the following aquitard wells in the Bear Creek Regime contained one or more dissolved VOCs with individual or summed concentrations of $5\mu g/L$ or more: GW-243 and GW-276 at the former S-3 Ponds; GW-008 and GW-087 at the Oil Landfarm; and GW-014, GW-046, GW-071, GW-072, GW-082, GW-288, GW-289, GW-291, GW-626, GW-627, and GW-653 at the BCBG WMA (Figure A.2). Analytical results for these wells show a wide range of summed VOC concentrations, with the lowest value (8 $\mu g/L$) reported for well GW-276 and the highest value (10,820 $\mu g/L$) reported for well GW-626. Also, as shown in Table 8, maximum concentrations of PCE, TCE, c12DCE, 11DCE, VC,

12DCA, CTET, MC, and benzene reported for several of these wells exceed the respective MCL for each compound.

Table 8. Bear Creek Regime CY 2002: maximum VOC concentrations in surveillance monitoring aquitard wells

Well				Conce	ntration (μg/L)			
Number	PCE	TCE	c12DCE	11DCE	VC	12DCA	CTET	MC	Benzene
GW-008	89	16	<	7					<
GW-014	21	160	970	37	87				<
GW-046	990	1,000	2,600	83	260	<			10
GW-071	390	110	, <	40	2 J				820
GW-082	<		1,100	43	290				45
GW-087	9	20	<						<
GW-243	4,400	20	<	<				120	
GW-276	10								
GW-288	250	14	<		4				
GW-289	690	14	<		2 J				
GW-291	380	42	<						
GW-626	920	710	7,200	120	1,200	32	8	6	190
GW-627	550	190	<	23	20				
GW-653	11	8	170	<					
MCL (µg/L)	5	5	70	7	2	5	5	5	5
Note: "." = No	t detected	; "<" = Les	s than MCL;	J = Estimate	ed concent	tration			

Monitoring results for these wells are discussed in sequence from hydraulically upgradient (north and east)

to hydraulically downgradient (south and west) in the Bear Creek Regime.

Historical monitoring data show that the highly contaminated groundwater in well GW-243 (and other aquitard monitoring wells located adjacent to the former S-3 Ponds) contains a mixture of dissolved VOCs dominated by very high PCE concentrations (>5,000 μ g/L) that indicate the likely presence of DNAPL in the Nolichucky Shale beneath the site (DOE 1997a). Several VOCs were detected in the groundwater samples collected from the well during CY 2002, with the highest concentrations reported for PCE (4,400 μ g/L), acetone (700 μ g/L), and MC (120 μ g/L); the PCE and MC concentrations exceed respective MCLs by several orders-of-magnitude (Table 8). The concentrations of VOCs in the well, as illustrated by the data for PCE and MC (Figure A.16), increased following closure of the former S-3 Ponds (1984) and installation of the low-permeability cap (1988) and reached peak post-closure levels during the early 1990s. Since then, VOC concentrations decreased through August 2002, when the concentrations of PCE (3,600 μ g/L) and MC (100 μ g/L) were the lowest since May 1989 (PCE = 2,300 μ g/L and MC = 87 μ g/L). Decreasing long-term concentrations of VOCs in the well reflect the cumulative effects of abiotic attenuation processes, including diffusion into the bedrock (matrix diffusion) beneath the site, because the highly mineralized and acidic pH of the groundwater in the well would not be expected to support biotic degradation of the VOCs.

The CY 2002 monitoring results for well GW-276 show that PCE continues to be the primary VOC in the shallow groundwater downgradient to the south-southeast of the former S-3 Ponds and that the concentrations of PCE in the well remain near 10 μ g/L. These PCE levels are substantially lower than that of other S-3 contaminants in the well (e.g., nitrate), which is probably a consequence of several factors, including the

comparably lower volume of VOCs in the nitric acid wastes routinely disposed at the site (DOE 1997a). Also, the overall lack of PCE degradation products in the well, particularly 12DCE isomers, suggest that biotic degradation may not be a significant natural attenuation mechanism in the vicinity of this well. Thus, the cumulative effects of various abiotic attenuation processes (e.g., adsorption, dilution, and dispersion) in the aquitard probably account for the continued reduction in the concentration of PCE in the groundwater at well GW-276, although the rate of decrease appears to have slowed, as illustrated by the PCE levels detected in the groundwater samples collected from the well in March 1994 (52 μ g/L), January 1998 (12 μ g/L), and January 2002 (8 μ g/L).

Well GW-087 is located on the western side of the former Boneyard/Burnyard, about 3,700 ft southwest of well GW-243 (Figure A.2), and is completed at a depth of about 20 ft bgs in the Nolichucky Shale (water table interval). Historical data for this well, which was last sampled in March 1999, show that it yields calcium-magnesium-bicarbonate groundwater that contains a mixture of dissolved VOCs, primarily PCE, TCE, and c12DCE. In March 2002, a groundwater sample was collected from the well before it was plugged and abandoned to accommodate CERCLA remedial action field work at the Boneyard/Burnyard (see Section 2.5.1.2). Analytical results for this sample show that the summed concentrations of PCE, TCE, and c12DCE (88 μ g/L) is more than 30% lower than evident in March 1999 (129 μ g/L). These results continue the decreasing concentration trends for PCE and TCE (Figure A.16), which have decreased by more than 95% from the respective peak levels evident in June 1987 (PCE = 1,600 μ g/L) and November 1987 (TCE = 800 μ g/L). Although substantially less than historical levels (e.g., 320 μ g/L in April 1997), the concentration of c12DCE evident in March 2002 (59 μ g/L) is nearly equal to that evident in March 1999 (55 μ g/L), which suggests a more stable concentration trend (Figure A.16). Decreasing concentrations of PCE and TCE in conjunction with increasing or stable c12DCE may be explained by the biotic degradation (reductive dechlorination) of PCE and TCE, which generally occurs as shown below (from Hinchee et al. 1995):

PCE
$$\div$$
 TCE + Chloride (Cl) \div DCE isomers + 2Cl \div VC + 3Cl \div Ethene + 4Cl.

This dechlorination process affects each of the compounds differently, with PCE being more readily dechlorinated because it is the most oxidized and VC being less susceptible to dechlorination because it is the least oxidized. Also, the consistent lack of VC in the groundwater at well GW-087 suggests that the dechlorination process is incomplete because of one or more limiting factors (e.g., the availability of electron donors) or that the VC does not accumulate because it is rapidly oxidized to carbon dioxide (Weidemeier et. al. 1996).

Well GW-008 is completed at a depth of about 25 ft bgs in the Nolichucky Shale (water table interval) along the south-central boundary of the Oil Landfarm WMA, about 850 ft northwest of well GW-087 (Figure A.2). Historical data show that well GW-008 yields acidic (pH <6) calcium-magnesium bicarbonate groundwater, distinguished by unusually low TDS (e.g., 75.8 mg/L in July 2002), which contains a mixture of dissolved VOCs originating from the Oil Landfarm (see discussion in Section 2.5.1.2). Analytical results for the groundwater samples collected from the well during CY 2002 show that PCE and TCE concentrations remain above respective MCLs (Table 8) and continue the generally increasing concentration trends evident for each compound (see Section 5.1). In contrast, more indeterminate concentration trends are indicated by the data for the other VOCs in the well, as illustrated by the 11DCE concentrations detected in the groundwater samples collected from the well in January 1998 (5 μ g/L), January 2000 (5 μ g/L), and January 2002 (6 μ g/L). The significance of these divergent concentration trends with respect to the relative flux of dissolved VOCs in the shallow groundwater downgradient of the Oil Landfarm is not apparent from the available data.

Well GW-014 is completed at a depth of about 13 ft bgs in the Nolichucky Shale (water table interval) near the eastern side of BG-A South (Figure A.2). Last sampled in August 1995, well GW-014 yields calcium-

magnesium-bicarbonate groundwater distinguished by unusually high concentrations of boron (e.g., 3.96 mg/L in August 2002) that probably reflect contamination from mop waters disposed in BG-A South (see Section 2.5.1.3). Groundwater in this well also contains a mixture of dissolved VOCs dominated by degradation products of PCE and 111TCA (c12DCE and 11DCA, respectively); the predominance of these compounds suggests that biotic degradation is a locally significant attenuation process. Monitoring results obtained during CY 2002 are consistent with historical data regarding the types of VOCs in the well and show the highest concentrations for c12DCE (970 $\mu g/L$) and 11DCA (200 $\mu g/L$), with lesser levels for PCE, TCE, 11DCE, and VC that remain above respective MCLs (Table 8). The CY 2002 monitoring data for each compound continue the decreasing concentration trends indicated by the historical (conventional sampling) results, as illustrated by the nearly complete (98%) decrease in the concentration of PCE between March 1987 (1,040 $\mu g/L$) and March 2002 (21 $\mu g/L$). Over this same period, however, the concentrations of (total) 12DCE and 11DCE decreased by 82% and 62%, respectively. This suggests that biotic degradation in the groundwater at this well may maintain the concentrations of 12DCE and 11DCE at the expense of their parent compounds.

Wells GW-071 and GW-072 comprise a well cluster located about 400 ft southwest (across geologic strike) of well GW-014 near the southeast corner of the BCBG WMA (Figure A.2). Both wells are completed in the Nolichucky Shale; GW-071 at a depth of about 220 ft bgs (intermediate bedrock interval) and GW-072 at a depth of about 98 ft bgs (shallow bedrock interval). These wells were last sampled in June 1991 and the respective monitoring data show that each well yields sodium-bicarbonate groundwater containing a mixture of dissolved VOCs dominated by PCE and 111TCA and their degradation products. Historical data show that VOC concentrations in the deeper groundwater at well GW-071 are much higher than in the shallower groundwater at well GW-072 and presampling groundwater elevations for these wells reflect vertically upward hydraulic gradients (i.e., groundwater elevations in well GW-071 are higher than in well GW-072). Thus, upward movement of VOC-contaminated groundwater from the deeper flow system (GW-071) may account for the presence of dissolved VOCs in the shallow flow system (GW-072). These historical findings are supported by several aspects of the monitoring results obtained during CY 2002: (1) summed VOC levels remain very high (>3,000 µg/L) in well GW-071, with the highest concentrations evident for 11DCA (1,780 μg/L), benzene (820 μg/L), PCE (390 μg/L), 111TCA (120 μg/L), and TCE (110 μg/L); (2) VOC concentrations in well GW-072 remain much lower than in well GW-071, with the highest concentrations evident for 11DCE (6 µg/L) and 11DCA (130 µg/L); and (3) presampling groundwater elevations in the wells reflect upward vertical hydraulic gradients (0.014 in February 2002 and 0.016 in August 2002). Additionally, the CY 2002 groundwater monitoring results for well GW-071 continue the divergent concentration trends indicated by the historical VOC data, with generally decreasing trends for PCE and TCE (Figure A.17), an indeterminate trend for 12DCE (Figure A.17), and clearly increasing trends for 11DCE, 111TCE, 11DCA, and benzene (see Section 5.1). The CY 2002 monitoring results also continue a generally increasing concentration trend for 11DCA in well GW-072 (see Section 5.1).

Well GW-046 yields calcium-magnesium-bicarbonate groundwater from a depth of 20 ft bgs in the Nolichucky Shale (water table interval) near the southwest corner of BG-A South about 900 ft directly west of wells GW-071/GW-072 (Figure A.2). Historical monitoring data show that the groundwater in well GW-046 contains a mixture of dissolved chlorinated solvents and petroleum hydrocarbons, with the very high concentrations (>1,000 µg/L) of several primary compounds (e.g., PCE) indicating the presence of DNAPL in the subsurface (DOE 1997a). The CY 2002 monitoring results show that the concentrations of PCE and TCE remain near 1,000 µg/L and that the concentrations of benzene, c12DCE, VC, and 11DCE exceed respective MCLs (Table 8). Some of the compounds detected in the well are probably present in the groundwater as a consequence of the biotic and/or abiotic degradation of related parent compounds. Additionally, inorganic chloride accumulates throughout the degradation of PCE and its daughter products, which may account for the unusually high chloride levels (e.g., 22.1 mg/L in January 2002) in the

groundwater samples from this well. Likewise, the acidity of the groundwater samples collected from this well (field pH measurements of 5.43 and 5.39 during CY 2002) is a potential indicator of the abiotic breakdown of dissolved 111TCA because nearly 80% of this compound may be chemically transformed to acetic acid (McCarty 1996). In any case, the CY 2002 monitoring results continue the widely variable, indeterminate long-term concentration trends indicated by the historical VOC data for this well, as illustrated by the PCE results reported for the groundwater samples collected from the well in August 1995 (460 μ g/L), July 2000 (8,400 μ g/L), and July 2002 (990 μ g/L).

Located about 500 ft directly west (parallel with geologic strike) of well GW-046, well GW-626 is part of a well cluster (with well GW-627) near the southwest corner of the BCBG WMA (Figure A.2). Completed at a depth of 78 ft bgs in the Nolichucky Shale (shallow bedrock interval) and last sampled in July 1998, historical data show that this well yields calcium-magnesium-bicarbonate groundwater distinguished by unusually high chloride levels (>40 mg/L) and a diverse mixture of dissolved VOCs, including chloroethenes, chloroethanes, and petroleum hydrocarbons. The source of the VOCs is believed to be DNAPL in the subsurface at BG-A South because: (1) a large mass of DNAPL (composed primarily of PCE and TCE) was encountered at a depth of 260 to 330 ft bgs in the Nolichucky Shale directly south (down geologic dip) of this site in January 1991 (Haase and King 1990b) and (2) the groundwater elevations in wells GW-626 and GW-627 indicate upward vertical hydraulic gradients (0.016 in February 2002 and 0.014 in July 2002). Monitoring results obtained during CY 2002 show that well GW-626 continues to yield groundwater samples distinguished by elevated chloride levels (42.5 mg/L in February 2002) and, as shown below in Table 9, high concentrations of several VOCs.

Table 9. Selected conventional sampling and low-flow sampling VOC results for well GW-626

				(Concentrati	ion (µg/L)			
VOC			Conventio	Low-Flow Sampling					
100	Feb. 1990	June 1990	Mar. 1991	Dec. 1991	Mar. 1993	Oct. 1993	July 1998	Feb. 2002	July 2002
PCE	3 J	2 J	8	730	140	32	11	920	320
TCE	4 J	3 J	11	890	110	36	11	710	190
12DCE (total)	16	7	70	280	1,200	330	13	7,200	1,500
11DCE		•	4 J	340	28	12	45	120	38
VC		•		47	72		•	1,200	42
111TCA	1 J	0.6 J	2 J	290	17	6	15	44	13
12DCA	2 J	•		3 J	•	3 J	15	32	7
11DCA		•	6	•	51	19	7	290	65
СТ				50				8	•
Chloroform				5				100	24
MC			•	FP	•	FP	•	6	•
Benzene	•	•	•	3 J	•	•	•	190	4 J

Note: "." = Not detected; J = Estimated concentration; FP = False positive result

Note that the CY 2002 monitoring results show substantially higher VOC concentrations in February 2002 (i.e., seasonally high flow conditions) than in August 2002 (i.e., seasonally low flow conditions). Conventional sampling results for the well show similarly wide temporal fluctuations in VOC levels, as illustrated by the CY 1993 data included in Table 9. These wide short-term fluctuations tend to mask the long-term trend of VOC concentrations in the well, which generally increased between February 1990 and December 1991, subsequently decreased through July 1998 and, based on the CY 2002 monitoring results, appear to have returned to the higher levels previously evident during the early 1990s.

The CY 2002 monitoring results show that the groundwater in well GW-627, which has been sampled on a continuous quarterly or semiannual frequency since March 1991, contains fewer VOCs at generally lower concentrations than evident in well GW-626. Completed at a depth of 270 ft bgs in the Nolichucky Shale (deep bedrock interval), well GW-627 yields sodium-chloride-bicarbonate groundwater that contains a mixture of dissolved VOCs dominated by PCE and TCE, which were first detected in this well following the discovery of the DNAPL in the Nolichucky Shale down-dip of BG-A South. Monitoring results obtained during CY 2002 show that maximum concentrations of PCE, TCE, 11DCE, and VC in the well remain above respective MCLs (Table 8). Results for these VOCs are consistent with the previous low-flow sampling data obtained since January 1998, but they differ substantially from the historical conventional sampling data for the well (Table 4). The sensitivity to the groundwater sampling method was confirmed by results of comparable sampling in February 2000, with the concentration of PCE detected in a groundwater sample obtained with the low-flow sampling method on February 21, 2000 (500 μ g/L) being almost an order-of-magnitude higher than the concentration of PCE (73 μ g/L) in the groundwater sample obtained with the conventional sampling method the next day (BWXT 2001a). Nevertheless, both the conventional sampling data and the low-flow sampling data indicate increasing concentrations of VOCs in the well (see Section 5.1).

Well GW-653 is completed at a depth of 39 ft bgs in the Nolichucky Shale (water table interval) northwest of wells GW-626 and GW-627, approximately 600 ft directly west of the BCBG WMA (Figure A.2). Historical data show that this well yields groundwater with a unique combination of geochemical characteristics: acidic pH (4.5 - 5.5) and very low dissolved solids, as reflected by the unusually low levels of calcium (<5 mg/L), magnesium (<2 mg/L), and bicarbonate (<20 mg/L). In addition to these distinctive geochemical characteristics, the historical data show that the groundwater in this well contains a mixture of dissolved VOCs, dominated by c12DCE. These VOCs are believed to originate from the waste disposal trenches in BG-A South (DOE 1997a). Monitoring results obtained during CY 2002 show that the well continues to yield acidic groundwater (field pH = 5.4 in February 2002 and 4.79 in July 2002) with unusually low dissolved solids (TDS = 40 mg/L in February 2002 and 60 mg/L in July 2002) and a mixture of PCE, TCE, c12DCE, 11DCE, 111TCA, and 11DCA. These results show that maximum concentration of c12DCE (170 μ g/L) remains substantially higher than that of the other compounds in the well, although the concentrations of PCE and TCE exceed respective MCLs (Table 8). Additionally, the CY 2002 monitoring results continue the increasing long-term concentration trend indicated by historical VOC data the for the well (see Section 5.1).

Wells GW-288 and GW-289 comprise a well cluster located adjacent to the western boundary of the BCBG WMA about 500 ft north (across geologic strike) of wells GW-626/GW-627 (Figure A.2). Both wells are completed in the Maryville Limestone; GW-288 at a depth of 60 ft bgs (shallow bedrock interval) and GW-289 at a depth of about 41 ft bgs (water table interval). These wells were last sampled in August 1995 and July 1998, respectively, and the monitoring results show that they both yield calcium-magnesium-bicarbonate groundwater containing a mixture of dissolved VOCs dominated by PCE. The CY 2002 monitoring results for these wells are consistent with respective historical data regarding the groundwater geochemistry and, as shown below in Table 10, the results for VOCs in each well are consistent with

historical data with respect to the types and relative concentrations of compounds detected, although the PCE concentrations are substantially lower compared to historical levels.

Table 10. Selected VOC results for wells GW-288 and GW-289

	Concentration (µg/L)								
Monitoring Well		Convention	Low-Flow	Sampling					
and VOC	April 1988	August 1988	February 1990	August 1995	March 2002	July 2002			
GW-288									
PCE	1,300	1,600	1,200	690 D	180	250			
TCE	11	11	12		11	14			
12DCE (total)	4 J				3 J	3 J			
VC					3 J	4 J			
GW-289									
PCE	1,300	800	590	930 D	670	690			
TCE	6	7			13	14			
12DCE (total)					2 J	2 J			
VC					2 J	2 J			
Note: "." = Not detected; J = Estim	nated concent	ration; D = D	iluted sample						

These results show that PCE remains the dominant VOC in the groundwater at both wells, with the highest PCE concentrations evident in the shallower groundwater at well GW-289, and reflect a fairly substantial decrease from historical PCE levels in each well. Also, the PCE concentrations in the deeper groundwater at well GW-288 appear to have decreased more rapidly. In contrast, the CY 2002 monitoring results for both wells indicate that the concentrations of PCE degradation products, particularly TCE, remain relatively unchanged (GW-288) or have slightly increased (GW-289) from the concentrations indicated by historical data. These results suggest that biotic degradation is an active VOC attenuation process in the groundwater at these wells.

Well GW-291 is completed at a depth of about 17 ft bgs in the Maryville Limestone (water table interval), approximately 500 ft northwest (hydraulically upgradient) of wells GW-288/GW-289 (Figure A.2). Last sampled in July 1998, the historical data show that well GW-291 yields calcium-magnesium-bicarbonate groundwater distinguished by very high boron concentrations (>2 mg/L). Groundwater in the well also contains a PCE-dominated mixture of dissolved VOCs that are believed to originate from the Walk-In Pits (DOE 1997a), which are located about 300 ft east (parallel with geologic strike) of the well. The monitoring results obtained during CY 2002 are consistent with the historical data and show, in addition to high boron levels (e.g., 2.42 mg/L in March 2002), that PCE continues to be the dominant VOC in the well, with concentrations remaining above 300 µg/L. Other compounds detected in the groundwater samples collected from the well during CY 2002 are TCE, c12DCE, 11DCA, and trichlorofluoromethane (TCFM). Low (estimated) concentrations were reported for each compound except TCE, which remains above 5 µg/L (Table 8). Additionally, the CY 2002 VOC results continue the generally decreasing concentration trends indicated by the historical data for the well, as illustrated by the PCE concentrations detected in the groundwater samples collected from the well in May 1988 (670 µg/L), June 1991 (600 µg/L), July 1998 (430 µg/L), and August 2002 (380 µg/L). Considering the very shallow depth of this well, the relatively slow

decrease in VOC concentrations suggest that the PCE-dominated plume of dissolved VOCs originating from the Walk-In Pits does not discharge extensively to the surface drainage system (DOE 1997a).

Located about 500 ft directly west (parallel with geologic strike) of well GW-291 (Figure A.2), well GW-082 is completed at a depth of 35 ft bgs in the Maryville Limestone (shallow bedrock interval). This well yields chloride-enriched calcium-magnesium-bicarbonate groundwater containing a mixture of dissolved VOCs that are believed to originate from waste disposal trenches within BG-C West (DOE 1997a), which occupies much of the northwestern "limb" of the BCBG WMA. The primary compounds in the groundwater at this well are c12DCE and 11DCA, which are degradation products of PCE and 111TCA, respectively. Based on the results for several indicator parameters, including the very low oxidation/reduction (REDOX) potential (e.g., -133 millivolts [mV] in February 2002), the groundwater in the well exhibits geochemical conditions frequently associated with biotic degradation of chlorinated hydrocarbons (Chapelle 1996), which also may explain why the shallow groundwater in this well contains unusually high chloride concentrations (e.g., 147 mg/L in February 2002). In any case, the concentrations of c12DCE (1,100 μ g/L), VC (290 μ g/L), 11DCA (1,600 μ g/L), and benzene (45 μ g/L) evident in February 2002 are the highest detected in the well. However, there is a clear difference between the concentrations of VOCs detected in groundwater samples collected with the conventional and low flow sampling methods, as illustrated by the data in Table 11.

Table 11. Conventional sampling and low-flow sampling VOC results for well GW-082

				Conce	entration	(μg/L)			
VOC	Conve	ntional Sa	mpling]	Low-Flow	Sampling	3	
	Mar. 1991	June 1992	Mar. 1993	June 1998	Mar. 1999	Feb. 2001	July 2001	Feb. 2002	July 2002
12DCE (total) 11DCE VC	72 •	· · 6	41 • 30	320 58	380 8 150	640 9 190	840 27 240	1,100 43 290	820 22 200
11DCA Chloroethane	•	•		3 J 15 J	410 12	360 28	1,200 18	1,600 17	730 25
Benzene	•	•	•	•	6	8	31	45	22
Note: "." = Not detected	; J = Estin	nated conc	entration						

Because the samples obtained with the conventional sampling method contain substantially lower VOC concentrations, it is not clear if the increasing concentration trend indicated by these data is an artifact of the change to low-flow sampling, or if the trend corresponds to an increase in the relative flux of dissolved VOCs along the flowpaths monitored by the well (see Section 5.1).

3.1.1.3 Radioactivity

As shown below in Table 12, elevated gross alpha activity (>15 pCi/L) and/or gross beta activity (>50 pCi/L) that exceed the associated minimum detectable activity (MDA) and the corresponding counting error (CE) were reported only for the groundwater samples collected during CY 2002 from six wells completed in the geologic formations that comprise the aquitard in the Bear Creek Regime (listed in sequence from hydraulically upgradient [north and east] to hydraulically down gradient [south and west]).

Table 12. Bear Creek Regime CY 2002: elevated gross alpha activity and gross beta activity in surveillance monitoring aquitard wells

Well	Date Sampled	G	Fross Alph (pCi		ity			Gross Beta Activity (pCi/L)		
	Sampled	MDA	Ac	tivity ±	CE	MDA	Ac	tivity :	± CE	
GW-243	03/21/02	44	540	±	190	220	13,000	±	520	
GW-243	08/13/02	740		<mda< td=""><td></td><td>840</td><td>17,000</td><td><u>±</u></td><td>1,300</td></mda<>		840	17,000	<u>±</u>	1,300	
GW-276	01/07/02	3.47	238.65	±	12.17	3.63	357.54	<u>±</u>	8.47	
GW-276	07/08/02	4.23	210.7	±	11.06	2.46	391.23	<u>±</u>	7.68	
GW-537	02/18/02	20		<mda< td=""><td></td><td>22</td><td>540</td><td>\pm</td><td>34</td></mda<>		22	540	\pm	34	
GW-537	07/31/02	14		<mda< td=""><td></td><td>36</td><td>640</td><td>\pm</td><td>51</td></mda<>		36	640	\pm	51	
GW-085	02/18/02	8.4		<mda< td=""><td></td><td>11</td><td>240</td><td>\pm</td><td>16</td></mda<>		11	240	\pm	16	
GW-085	07/31/02	6.4		<mda< td=""><td></td><td>9.6</td><td>220</td><td>\pm</td><td>15</td></mda<>		9.6	220	\pm	15	
GW-087	03/25/02	2.3	20	±	5	10		<		
GW-627	07/29/02	10	19 Q	±	9.9	18		<mda< td=""><td></td></mda<>		
Screenin	g Level		15 pC	Ci/L			50 pC	i/L	•	

Note: "<" = Less than screening level; Q = Qualitative result

Alpha radioactivity in the groundwater at most of these wells is primarily from uranium isotopes and beta radioactivity in these wells is primarily from Tc-99. Under oxidizing conditions, Tc-99 occurs as the pertechnetate anion (TcO_4) which is soluble and highly mobile in groundwater (Gee et al. 1983), whereas the uranium isotopes occur as uranyl cations, which are prone to pH-sensitive sorption reactions (Fetter 1993) and, consequently, are much less mobile in the groundwater than Tc-99.

Historical monitoring data for well GW-243 show that the groundwater in the Nolichucky Shale nearest to the former S-3 Ponds has some of the highest levels of radioactivity in the Bear Creek Regime. Available data show that the radioactivity in the groundwater is from Np-237, radium, strontium-89/90, Tc-99, and uranium isotopes (U-234 and U-238) and associated decay products, primarily thorium-234 (Th-234). Several of these radionuclides were detected (i.e., activity >MDA and CE) in the groundwater samples collected from well GW-243 during CY 2002, with the highest activities evident for Tc-99 (14,000 pCi/L), U-238 (270 pCi/L), Th-234 (270 pCi/L) (which is presumed to be in equilibrium with U-238), U-234 (110 pCi/L), total radium (53 pCi/L), Np-237 (32 pCi/L), and strontium-89/90 (32 pCi/L). Note that the Tc-99 activity is almost four times higher than the SDWA threshold level for a 4 mrem/yr dose equivalent (4,000 pCi/L). These results are generally consistent with historical data, although few of the groundwater samples previously collected from the well were analyzed for radionuclides and data obtained before January 1990 is considered qualitative because the necessary DQO information (i.e., MDA and CE) associated with each result are not available. Additionally, the CY 2002 monitoring results reflect a continued decrease in the levels of alpha and beta radioactivity in the well (Figure A.18), with a particularly large proportional decrease (85%) in gross alpha activity between March 1994 (3,530 pCi/L), which is the last time the well was sampled, and March 2002 (540 pCi/L). This large proportional decrease in gross alpha activity mirrors that of the total uranium concentrations in the well, as noted in Section 3.1.1.1, and likewise may indicate a significant reduction in the relative flux of uranium isotopes along the groundwater flowpaths in the Nolichucky Shale that are monitored by well GW-243.

Historical groundwater monitoring data show that the elevated alpha radioactivity in the Nolichucky Shale at well GW-276 is primarily attributable to U-238, U-234, and Np-237 in the groundwater and that the bulk

of the gross beta activity is attributable to Tc-99. Also, Th-234 is a likely source of beta radioactivity in the well (assuming equilibrium with U-238). Results of radiological analyses of the groundwater samples collected from the well during CY 2002 are generally consistent with historical data, with the highest activities evident for Np-237 (16 pCi/L), U-234 (80 pCi/L), and U-238 (194 pCi/L). Also, the results for U-234 and U-238 continue the temporally variable but generally decreasing long-term activity trends indicated by historical data for the well. Although the Tc-99 activities reported for the groundwater samples collected from the well during CY 2002 exceed 500 pCi/L, they are substantially below the SDWA threshold level (4,000 pCi/L) for a 4 mrem/yr dose equivalent from Tc-99. Additionally, the CY 2002 monitoring results for Tc-99 continue the decreasing activity trend indicated by historical data for the well, as illustrated by the Tc-99 results reported for the groundwater samples collected from the well in August 1994 (1,120 pCi/L), July 1998 (840 pCi/L), and July 2002 (501 pCi/L).

Analytical results obtained during CY 2002 show that beta radioactivity in the shallow groundwater at wells GW-085 and GW-537 remains substantially above 50 pCi/L (Table 12). These results are consistent with respective historical data for each well and reflect the migration of Tc-99 via strike-parallel flowpaths in the Nolichucky Shale west of the former S-3 Ponds (DOE 1997a). Very low (background) levels of alpha radioactivity in the groundwater at both of these wells, as illustrated by the CY 2002 gross alpha results (<MDA) for each well (Table 12), reflects the greater attenuation of uranium isotopes relative to Tc-99. Moreover, the CY 2002 monitoring results for both wells continue the widely variable but generally increasing trends for gross beta activity (see Section 5.1).

Historical groundwater monitoring data show that the elevated levels of alpha radioactivity in the Nolichucky Shale at well GW-087 is from uranium isotopes, which are believed to originate from the radiological wastes associated with the former Boneyard/Burnyard (DOE 1997a) that were excavated and removed during the CERCLA remedial actions at the site (see Section 2.5.1.2). Gross alpha activity reported for the groundwater sample collected from this well in March 2002 (20 pCi/L) slightly exceeds the MCL and continues the decreasing trend indicated by historical data, as illustrated by the gross alpha activity reported for the samples collected from the well in April 1988 (132 pCi/L), March 1990 (54 pCi/L), and March 1999 (36 pCi/L).

Elevated gross alpha activity reported for the groundwater sample collected from well GW-627 in July 2002 (19 pCi/L) is not supported by the historical data for the well and is probably an analytical artifact. Gross alpha activity for all but two of the 35 samples collected from the well between March 1991 and February 2002 does not exceed either the MDA or the CE associated with each result.

3.1.2 Aquifer Monitoring Wells

Elevated concentrations (> screening level) of one or more of the principal groundwater contaminants in the Bear Creek Regime were detected in the groundwater samples collected during CY 2002 from 22 monitoring wells that are completed in the formations which comprise the aquifer (Maynardville Limestone or Knox Group) and serve the surveillance monitoring purposes of DOE Order 5400.1 (Table 13).

Table 13. Bear Creek Regime CY 2002: principal groundwater contaminants detected in surveillance monitoring aquifer wells

Well	Monitored	Inorg	anics	MOG	Radioa	ctivity
Number	Interval Depth (ft bgs)	Nitrate	Uranium	VOCs	Alpha Activity	Beta Activity
GW-061	17.5 - 24.6	•	•		•	•
GW-066	50.0 - 54.9			•		
GW-225	150.0 - 200.0	•		•		
GW-226	45.0 - 55.0	•		•		
GW-229	40.0 55.0		•	•	•	•
GW-315	90.0 - 104.0			•		
GW-683	133.9 - 196.8	•	•		•	
GW-684	106.4 - 128.4		•		•	
GW-694	154.0 - 204.5		•		•	
GW-695	50.6 - 62.6	•				•
GW-703	135.0 - 182.0	•		•		•
GW-704	246.0 - 256.0	•		•		
GW-706	157.0 - 182.5	•	•	•	•	•
GW-723	340.6 - 444.5		•	•		
GW-724	289.6 - 301.6	•	•	•		
GW-725	132.5 - 142.5	•		•		
GW-736	92.0 - 105.0	•		•	•	•
GW-737	79.0 - 89.5	•	•	•		
GW-738	63.5 - 88.0	•		•		•
GW-739	289.2 - 320.0			•		
GW-740	165.6 - 190.0			•		
GW-835	17.2 - 19.2	•	•		Not Analyzed	Not Analyzed
Scre	eening Level	10 mg/L	0.03 mg/L	5 μg/L	15 pCi/L	50 pCi/L

Fifteen of these wells are components of three Exit Pathway Pickets in the Bear Creek Regime: Picket A (GW-683 and GW-684), Picket B (GW-694, GW-695, GW-703, GW-704, and GW-706), and Picket C (GW-723, GW-724, GW-725, GW-736, GW-737, GW-738, GW-739, and GW-740). The wells that comprise each Exit Pathway Picket are completed at various depths within different hydrostratigraphic zones along a strike-normal transect across the Maynardville Limestone and lower Knox Group. The remaining wells are located in several areas of the Bear Creek Regime, including one well near the eastern end of the regime at Spoil Area I (GW-315); one well on the north side of Bear Creek about 750 ft downstream of the former S-3 Ponds (GW-835); one well (GW-066) adjacent to Bear Creek near the former Boneyard/Burnyard; three wells near Bear Creek south of the Oil Landfarm WMA (GW-225, GW-226, and GW-229); and one well near Bear Creek south of the BCBG WMA (GW-061).

3.1.2.1 Inorganic Contaminants

As shown below in Table 14, elevated concentrations of nitrate (>10 mg/L) and/or total uranium (>0.03 mg/L) were reported for at least one groundwater sample collected during CY 2002 from 17 of the surveillance monitoring wells that are completed in the geologic formations which comprise the aquifer in the Bear Creek Regime.

Table 14. Bear Creek Regime CY 2002: elevated nitrate and uranium concentrations in surveillance monitoring aquifer wells

Wall I and on / Num	ala ou	Distance and Direction		rate g/L)		nium g/L)
Well Location / Nun	iber	from S-3 Site (Figure A.2)	1st Qtr. 2002	3rd Qtr. 2002	1st Qtr. 2002	3rd Qtr. 2002
S-3 Site	GW-835	750 ft West	19.9	15	1.21	1.45
Exit Pathway Picket C	GW-724 GW-725 GW-736 GW-737 GW-738	3,000 ft West	25.8 48.2 17.8 14.2 17.2	12 18.5 15.3 11.6 15.1	< < < <	· < < <
Oil Landfarm WMA	GW-225 GW-226 GW-229	4,500 ft West 5,000 ft West	37.4 10.3	34.9 12.2	< c c c c c c c c c c c c c c c c c c c	< < < 0.266
Exit Pathway Picket B	GW-694 GW-695 GW-703 GW-704 GW-706	7,000 ft West	1220.814.536.8	10.820.71215.7	0.0393 <	0.0355 < < < 0.106
BCBG WMA	GW-061	9,000 ft West	13.2	<	0.0642	0.0581
Exit Pathway Picket A	GW-683 GW-684	10,000 ft West	13.3	< <	0.0485 0.0454	< <
N	ICL		10 n	ng/L	0.03	mg/L
Note: "." = Not detected; "<	" = Less than	n MCL	I			

The groundwater contaminant plume emplaced during operation of the former S-3 Ponds is the likely source of the nitrate in each of these wells. Elevated concentrations of uranium in the groundwater at well GW-835 also reflect migration from the former S-3 Ponds, but the former Boneyard/Burnyard is the more likely source of the uranium in the groundwater at well GW-229 and Exit Pathway Picket B wells GW-694 and GW-706. Influx of uranium from sources within the BCBG WMA also may contribute to the uranium levels in the groundwater at well GW-061 and Exit Pathway Picket A wells GW-683 and GW-684.

Well GW-835 is completed at a depth of 19 ft bgs in the Maynardville Limestone (water table interval) north of Bear Creek near the contact with the underlying Nolichucky Shale (Figure A.2). This well is believed to monitor some of the primary strike-parallel contaminant migration pathways west of the site that discharge into NT-1 (DOE 1997a). Historical data show that this well yields sulfate-enriched calcium-magnesium-bicarbonate groundwater containing moderately elevated (> 10 mg/L) nitrate levels and very high (>1 mg/L) total uranium concentrations. Analytical results obtained during CY 2002 are consistent with these historical findings and show that the nitrate and uranium concentrations in the well remain above respective MCLs (Table 14), with the highest concentration of nitrate (19.9 mg/L) reported for the sample obtained in March 2002 (seasonally high flow conditions) and the highest uranium concentration (1.45 mg/L) reported for the sample obtained in August 2002 (seasonally low flow conditions). The CY 2002 monitoring results for nitrate continue the seasonally fluctuating and generally decreasing concentration trend indicated by historical data for the well, with the nitrate concentration evident in November 2002 (6.5 mg/L) being the lowest level detected in the well. Uranium results obtained during CY 2002 continue the generally indeterminate long-term concentration trend indicated by historical data for the well, as illustrated by the

uranium concentrations reported for the groundwater samples collected from the well in June 2000 (1.05 mg/L), November 2001 (1.36 mg/L), and November 2002 (1.31 mg/L).

Monitoring results obtained during CY 2002 show that nitrate concentrations in the groundwater at Exit Pathway Picket C wells GW-724, GW-725, GW-736, GW-737, and GW-738 remain above the MCL (Table 14). The highest nitrate concentration was reported for the groundwater sample collected from well GW-725 in January 2002 (42.8 mg/L), but this result may be an outlier because it is about 200% higher than the nitrate results for all of the other samples collected from the well (e.g., 18.5 mg/L in July 2002). The next highest nitrate concentration at Exit Pathway Picket C (25.8 mg/L) was reported for the deepest well (GW-724; 301 ft bgs). Higher concentrations of nitrate (and other contaminants) usually occur in the deeper flow system in the Maynardville Limestone because attenuation (including discharge into Bear Creek) occurs more rapidly in the shallow karst network (DOE 1997a). Also, the highest nitrate concentrations reported for the groundwater samples collected from wells GW-736 (17.8 mg/L) and GW-737 (14.2 mg/L) during CY 2002 are about 50% lower than the nitrate concentrations (31 mg/L and 33 mg/L, respectively) evident when the wells were last sampled in September 1995. Similarly decreasing nitrate concentration trends are indicated by the CY 2002 results for wells GW-724 and GW-738 (Figure A.19). Decreasing nitrate concentrations in the groundwater at Exit Pathway Picket C primarily reflect the substantially reduced nitrate flux following closure of the former S-3 Ponds and the combined effects of natural attenuation processes in the aquifer (DOE 1997a). Excluding the suspected outlier result from January 2002, nitrate concentrations in well GW-725 also exhibit a decreasing long-term concentration trend, but the magnitude of the concentration decrease may be an artifact of the sampling method (BWXT 2001a). Nevertheless, separate plots of the conventional sampling and low-flow sampling results for nitrate both show generally decreasing concentration trends (Figure A.20).

Well GW-226 is the shallower well (55 ft bgs) of a two-well cluster (with GW-225) located south of the main channel of Bear Creek about 1,500 ft downstream (west) of Exit Pathway Picket C (Figure A.2). Completed in the Maynardville Limestone (shallow bedrock interval), this well yields calcium-magnesium-bicarbonate groundwater with nitrate concentrations that fluctuate above and below the MCL. For example, nitrate concentration detected in the groundwater sample collected from the well in August 2001 (7.98 mg/L) is slightly below the MCL whereas the nitrate concentration reported for the sample obtained in August 2002 (12.2 mg/L) is slightly above the MCL. Also, the low-flow sampling results show generally lower nitrate levels than indicated by historical conventional sampling data, which may reflect bias from the groundwater sampling method (Table 4). Plotted separately, the conventional sampling nitrate results (January 1986-May 1991) show a generally decreasing concentration trend, whereas the low-flow sampling nitrate results (March 1998 - August 2002) indicate a more indeterminate concentration trend (Figure A.21).

Well GW-225 is completed with a an open-hole interval from 150 - 200 ft bgs in the lower section of the Maynardville Limestone. Historical monitoring data show that this well yields chloride- and sulfate-enriched calcium magnesium-bicarbonate groundwater that contains nitrate levels, which exceed the MCL and are substantially higher than evident in well GW-226. Higher relative concentrations of nitrate in the deeper groundwater at well GW-225 are believed to be a consequence of the inflow of nitrate-contaminated groundwater into the deeper bedrock in the Maynardville Limestone via the flowpaths associated with a losing reach of Bear Creek south of the Oil Landfarm WMA (DOE 1997a). Monitoring results obtained during CY 2002 confirm data obtained during CY 2001 showing nitrate levels that remain above the MCL but are about 50% lower than evident during the early 1990s, as illustrated by the nitrate concentrations detected in the groundwater samples collected from the well in March 1992 (73 mg/L), March 2001 (35.4 mg/L), and February 2002 (37.4 mg/L). As noted in Section 3.0, however, the lower nitrate levels may be an artifact of the change from conventional sampling to low-flow sampling (Table 4). Thus, it is not clear from the available data if the decrease in the concentration of nitrate in well GW-225 is an artifact of the

sampling method or if it reflects a reduction in the relative flux of nitrate along the flowpaths monitored by the well. Plotted separately, the conventional sampling data (January 1986 - September 1992) show an increasing concentration trend for nitrate whereas the low-flow sampling results (March 2001 - August 2002) indicate an indeterminate nitrate concentration trend (Figure A.22).

Well GW-229 is completed at a depth of 55 ft bgs in the Maynardville Limestone (shallow bedrock interval) north of the main channel of Bear Creek about 450 ft downstream (west) of wells GW-225 and GW-226 (Figure A.2). Last sampled in September 1995, the historical data for well GW-229 indicate that it monitors sodium- and chloride-enriched calcium-magnesium-bicarbonate groundwater distinguished by very high concentrations of boron, iron, and uranium. The former Boneyard/Burnyard is believed to have been the primary source of the uranium in the groundwater at this well, which was sampled shortly before (March 2002) and after (August 2002) the removal of radiological wastes from the site (see Section 2.5.1.2). Monitoring results obtained during CY 2002 show that the well continues to yield groundwater samples containing elevated uranium concentrations (>0.03 mg/L) along with unusually high levels of boron (>3 mg/L), iron (>20 mg/L), sodium (>65 mg/L), and chloride (>100 mg/L). Not only are the uranium concentrations above the MCL (Table 14), but both results also are almost an order-of-magnitude higher than the historical maximum uranium concentration for this well (0.042 mg/L in September 1988). However, it is possible that the higher uranium concentrations are an artifact of the change from conventional sampling to low-flow sampling. Thus, it is not clear from the available data if the apparent increase in the concentration of dissolved uranium in well GW-229 is a sampling artifact or if it reflects an increase in the overall flux of uranium via the flowpaths in the Maynardville Limestone that are monitored by the well.

The monitoring results obtained during CY 2002 show that nitrate concentrations in the Maynardville Limestone at Exit Pathway Picket B wells GW-695, GW-703, GW-704, and GW-706 exceed the MCL (Table 14). The nitrate results for these wells, which are located about 2,000 ft west (downgradient) of well GW-229 (Figure A.2), are consistent with respective historical data and show that nitrate levels in the shallow groundwater (i.e., GW-695) remain lower than the nitrate levels in the deeper groundwater (i.e., GW-706). Additionally, the CY 2002 monitoring data continue the seasonally variable and relatively indeterminate concentration trends evident for wells GW-703 and GW-704 (Figure A.23) and the generally increasing longterm concentration trend indicated by historical data for well GW-695 (see Section 5.1). The CY 2002 monitoring results for well GW-706 also show higher nitrate concentrations than indicated by historical levels, but this may be an artifact of the sampling method because data obtained from during CY 2000 show that groundwater samples collected from this well with the low-flow sampling method contain higher nitrate levels than samples collected with the conventional sampling method (BWXT 2001a). Plotted separately, nitrate results obtained with the conventional sampling method (June 1991 - September 1992; February and July 2000) reflect a variable but generally decreasing concentration trend, and the low-flow sampling results (January 1998 - August 2002) reflect a similarly decreasing trend, excluding the concentration "spike" (99.1 mg/L) in January 2001 (Figure A.24).

In addition to elevated nitrate levels in the Maynardville Limestone at the Exit Pathway Picket B wells, the CY 2002 monitoring results show that total uranium concentrations in the groundwater at well GW-694 slightly exceed the MCL and that uranium levels in the groundwater at well GW-706 remain substantially above the MCL (Table 14). The source of the uranium in the groundwater at these wells is believed to be the former Boneyard/Burnyard (DOE 1997a), which is about 3,500 ft east (hydraulically upgradient) of Exit Pathway Picket B. Moreover, the lack of elevated total uranium concentrations in the other Picket B wells suggest migration of the uranium via fairly discrete (strike-parallel) transport pathways in the Maynardville Limestone. Monitoring results obtained during CY 2002 show that uranium levels in the groundwater at well GW-694 have decreased by almost an order-of-magnitude from historical levels (Figure A.25), although this well has a substantial gap (August 1996 - March 2002) in its sampling history

that spans the change from conventional sampling to low-flow sampling. In contrast to the nitrate results for well GW-706, the uranium concentrations for this well do not indicate any significant difference between conventional and low-flow sampling data and reflect an indeterminate long-term concentration trend (Figure A.25) punctuated by occasional concentration "spikes" (e.g., 0.277 mg/L in February 2000).

Well GW-061 is completed at a depth of about 25 ft bgs in the Maynardville Limestone (water table interval) south of the main channel of Bear Creek approximately 1,800 ft downstream of Exit Pathway Picket B (Figure A.2). Last sampled in September 1995, the historical monitoring results for this well show that it yields calcium-magnesium-bicarbonate groundwater distinguished by unusually high iron concentrations and nitrate and total uranium levels which sporadically exceed respective MCLs. Monitoring results obtained during CY 2002 are generally consistent with these historical findings, although both samples collected from the well during CY 2002 contained significant suspended solids, which probably explains the very high iron concentration in the sample collected in August 2002 (total suspended solids = 248 mg/L and total iron = 17.8 mg/L). Both samples also contained elevated nitrate and uranium levels, with the highest concentration of each contaminant (13.2 mg/L and 0.0642 mg/L, respectively) detected in the groundwater sample collected from the well in March 2002 (seasonally high flow conditions). The nitrate results continue the indeterminate concentration trend indicated by historical data for the well, as illustrated by the nitrate levels evident in August 1989 (9 mg/L), June 1991 (6 mg/L), June 1995 (15 mg/L) and August 2002 (8.73 mg/L). A similarly indeterminate long-term concentration trend also is evident for uranium in the well, as illustrated by the nearly equal concentrations of uranium detected in the groundwater samples collected from the well in September 1995 (0.057 mg/L) and August 2002 (0.0581 mg/L). However, the uranium concentrations in these samples are higher than the uranium levels evident in the well during the late 1980s and early 1990s (e.g., 0.033 mg/L in August 1989 and 0.025 mg/L in June 1991).

The wells that comprise Exit-Pathway Picket A are located near the confluence of NT-8 and the main channel of Bear Creek, approximately 1,700 ft downstream (west) of well GW-061 (Figure A.2), and Picket A wells GW-683 and GW-684 were sampled during CY 2002. These wells are completed in the lower Knox Group (GW-683) and upper Maynardville Limestone (GW-684) at depths of 197 ft and 128 ft bgs, respectively. Historical monitoring data show that these wells yield calcium-magnesium-bicarbonate groundwater with nitrate and uranium concentrations that sporadically exceed respective MCLs. Monitoring results obtained during CY 2002, which show elevated nitrate concentrations in the groundwater at well GW-683 and elevated uranium levels in both wells (Table 14), are consistent with the historical data. As in previous years, the highest nitrate and uranium concentrations were reported for the groundwater samples collected from each well during seasonally high flow conditions (January 2002), which suggests seasonally variable flux of contaminants via the flowpaths monitored by these wells. These seasonal fluctuations dominate the nitrate concentration trend for well GW-683 (Figure A.26). The uranium concentrations in each well reflect a similarly variable, indeterminate trend (Figure A.26), as illustrated by the uranium results reported for the groundwater samples collected from well GW-683 in February 1999 (0.0446 mg/L), July 2000 (0.0203 mg/L), January 2001 (0.058 mg/L), and July 2002 (0.0231 mg/L). Elevated uranium concentrations in the groundwater at these wells probably reflect downgradient, strike-parallel transport of uranium released from the radiological wastes associated with the former Boneyard/Burnyard (DOE 1997a). If so, then the removal of the wastes from the site during the CERLCA remedial action completed in May 2002 (see Section 2.5.1.2) should result in the eventual reduction of uranium levels in the groundwater at well GW-683.

3.1.2.2 Volatile Organic Compounds

One or more dissolved VOCs were detected at individual or summed concentrations of $5 \mu g/L$ or more in at least one groundwater sample collected during CY 2002 from 18 of the surveillance monitoring wells that are completed in the geologic formations which comprise the aquifer in the Bear Creek Regime (Table 13). As shown in Table 15, the maximum concentrations of PCE, TCE, c12DCE, 11DCE, VC, CTET, and benzene reported for at least one groundwater sample from 16 of these wells (arranged in order from hydraulically upgradient [east] to downgradient [west]) exceed respective MCLs.

Table 15. Bear Creek Regime CY 2002: maximum VOC concentrations in surveillance monitoring aquifer wells

Concentration (µg/L)										
PCE	TCE	c12DCE	11DCE	VC	CTET	Benzene				
11	5 J	<								
	6									
<	110	<			<					
<	200	<	<		7					
<	9	<								
<	7	<								
	37	<								
	37									
	58	<								
8	5 J	<								
	190	<	<		<					
	110	<								
		110	11	40		8				
	16	<								
	45	<	<							
•	17	<				•				
5	5	70	7	2	5	5				
	11 . < < < < < < < < < <	11 5 J . 6 . 110 . 200 . 9 . 7 . 37 . 37 . 58 8 5 J . 190 . 110 16 . 45 . 17	PCE TCE c12DCE 11 5 J . 6 . <	PCE TCE c12DCE 11DCE 11 5 J . . 6 . . <	PCE TCE c12DCE 11DCE VC 11 5 J .	PCE TCE c12DCE 11DCE VC CTET 11 5 J .				

Note: "." = Not detected; "<" = Less than MCL; J = Estimated concentration

Historical monitoring data show that the groundwater in the Maynardville Limestone at well GW-315 contains a mixture of PCE, TCE, and c12DCE that is believed to originate from Spoil Area I or possibly the Fire Training Facility, which is a confirmed source of VOCs located in the East Fork Regime about 1,000 ft east of the well (DOE 1997a). Each of these compounds were detected in the groundwater samples collected from the well during CY 2002, which contained relatively low summed VOC concentrations ($<20 \,\mu\text{g/L}$) with maximum concentrations of PCE and TCE equal to or greater than the respective MCL (Table 15). Although the CY 2002 monitoring results show that the concentrations of VOCs in the groundwater at this well are much lower than the peak concentrations evident during the early 1990s (e.g., PCE = 38 $\,\mu\text{g/L}$ in January 1991), they continue a fairly indeterminate concentration trend evident since the mid 1990s, as illustrated by the PCE results reported for the groundwater samples collected from the well in August 1996 (14 $\,\mu\text{g/L}$), August 1998 (11 $\,\mu\text{g/L}$), September 2000 (10 $\,\mu\text{g/L}$), and July 2002 (11 $\,\mu\text{g/L}$).

Historical monitoring data show that the groundwater in the Maynardville Limestone at all eight Exit Pathway Picket C wells (GW-723, GW-724, GW-725, GW-736, GW-737, GW-738, GW-739, and GW-740) contains

a mixture of dissolved VOCs dominated by TCE. The primary source of the VOCs in these wells is believed to be the Rust Spoil Area (TCE), with other upgradient sources, including the contaminant plume emplaced during operation of the former S-3 Ponds, accounting for the lesser levels of the other VOCs (e.g., c12DCE) in these wells (DOE 1997a). The CY 2002 monitoring results show that the TCE concentrations in the groundwater at each of the Exit Pathway Picket C wells exceed the MCL, with a conspicuously high TCE concentration (200 μ g/L) reported for the groundwater sample collected from well GW-725 in January 2002 (TCE = 15 μ g/L in July 2002). As noted in Section 3.1.1.2, this sample also contained an unusually high concentration of nitrate. Groundwater samples were collected from well GW-725 on January 31, 2002 and data from a rain gauge in BCV show that 8.6-inches of rain fell during the preceding two weeks, including 5.8-inches the week before the sampling date. It is possible the January 2002 results for TCE and nitrate reflect a temporal "spike" in the relative (advective) flux of these contaminants along the flowpaths in the Maynardville Limestone that are monitored by well GW-725.

As shown on Figure A.27, the CY 2002 results for TCE in the Exit Pathway Picket C wells continue the generally decreasing concentrations trends indicated by historical data for the shallower wells (GW-736, GW-737, and GW-738) and fairly indeterminate concentration trends indicated by the historical data for the deeper wells (GW-723, GW-724, GW-739, and GW-740). A decreasing concentration trend also is evident for TCE in well GW-725, but this trend may be at least partially attributed to the change in the groundwater sampling method because the findings of a study performed during CY 2000 demonstrated substantially higher TCE concentrations in samples collected with the conventional sampling method (BWXT 2001a). Plotted separately, the conventional sampling results (March 1992 - September 1997) indicate an indeterminate TCE concentration trend whereas the low-flow sampling results (March 1998 - July 2002) reflect a more clearly decreasing trend, excluding the concentration "spike" from the January 2002 sampling result for TCE (Figure A.28).

Well GW-066 is located on the north side of the main channel of Bear Creek approximately 225 ft downstream of Exit Pathway Picket C and is completed at a depth of 25 ft bgs in the lower Maynardville Limestone (shallow bedrock interval) near the geologic contact with the Nolichucky Shale (Figure A.2). Historical data for this well, which was sampled only once (September 1995) before CY 2002, indicate that it yields sulfate-enriched calcium-magnesium-bicarbonate groundwater containing relatively low levels of dissolved VOCs dominated by PCE (21 μ g/L) and TCE (12 μ g/L). The groundwater monitoring results obtained during CY 2002 confirm these data and show that the well continues to yield groundwater samples with unusually high sulfate (120 mg/L in March 2002) combined with low (<20 μ g/L) summed concentrations of PCE, TCE, and c12DCE, although the PCE levels evident in March 2002 (8 μ g/L) and August 2002 (6 μ g/L) slightly exceed the MCL (5 μ g/L). Compared to the respective concentrations evident in September 1995, these results suggest an overall decrease in the concentration of dissolved VOCs in the groundwater at well GW-066.

Historical monitoring data show that the shallow groundwater in the Maynardville Limestone at well GW-226 contains a mixture of dissolved VOCs, dominated by TCE with lesser amounts of c12DCE and 11DCE. The types and concentrations of dissolved VOCs in the groundwater at this well are believed to reflect influx from the former Boneyard/Burnyard/HCDA (DOE 1997a). The monitoring results obtained during CY 2002 show that concentrations of TCE in this well exceed 100 μ g/L whereas maximum c12DCE and 11DCE concentrations remain below respective MCLs (Table 15). These TCE levels are similar to those evident in the well since March 1998 (TCE = 110 μ g/L), which is the first time the low-flow sampling method was used at this well, but are substantially higher than the TCE concentration evident in May 1991 (3 μ g/L), which is the last time the conventional sampling method was used at this well. Conversely, the concentrations of c12DCE in each of the samples collected from the well between May 1998 (7 μ g/L) and August 2002 (3 μ g/L) are much lower than evident in May 1991 (29 μ g/L). Moreover, nearly equal concentrations of

11DCE were detected in the groundwater samples collected in May 1991 (1 μ g/L) and May 1998 (2 μ g/L) and 11DCE was not detected in either sample collected from the well during CY 2002. Thus, it is not clear to what degree, if any, the groundwater sampling method may influence the VOC results for this well, or if the difference between the VOC data corresponds to a significant change in the relative flux of VOCs during the seven year gap in the sampling history for the well. Plotted separately (Figure A.29), the respective conventional sampling and low-flow sampling results for TCE show decreasing concentration trends.

Historical monitoring data show that the groundwater in the Maynardville Limestone at well GW-225 also contains a TCE-dominated mixture of dissolved VOCs, with summed concentrations that are generally higher than evident in the shallower groundwater at well GW-226. Higher relative concentrations of VOCs in deeper groundwater at well GW-225 are believed to be a consequence of contaminated groundwater entering the deeper flow system in the Maynardville Limestone via flowpaths associated with a losing reach of Bear Creek south of the Oil Landfarm WMA (DOE 1997a). Monitoring results obtained during CY 2002 are consistent with historical data and show that summed VOC concentrations in well GW-225 remain near 200 $\mu g/L$. Trichloroethene is the dominant compound detected in the groundwater samples collected in February (190 $\mu g/L$) and August 2002 (180 $\mu g/L$); low (estimated) concentrations of c12DCE, 11DCE, and CT also were detected in these samples. Although the TCE concentrations remain substantially higher than the MCL (5 $\mu g/L$), they reflect a decrease of almost 60% from the TCE levels evident in March (370 $\mu g/L$) and September 1992 (360 $\mu g/L$), which is the last time the well was sampled before March 2001. In conjunction with decreasing TCE concentrations evident in the shallower groundwater at well GW-226, the reduced levels of TCE in the deeper groundwater at well GW-225 further support a continued decrease in the relative flux of dissolved VOCs via the groundwater transport pathways monitored by these wells.

Historical monitoring results show that the groundwater in the Maynardville Limestone at well GW-229 contains a diverse mix of dissolved VOCs, including benzene, 12DCE, TCE, 11DCE, 11DCA, with the highest concentrations reported for (total) 12DCE (>50 µg/L) and 11DCA (20 µg/L). These compounds are degradation products of PCE and 111TCA, respectively, and the strongly negative REDOX measurements for the well (e.g., -127 mV in August 2002) indicate reducing conditions that favor the biotic degradation of chlorinated hydrocarbons in the groundwater. Monitoring results obtained during CY 2002 show that the c12DCE concentrations in the shallow groundwater at this well exceed 100 µg/L, which is higher than the MCL (70 µg/L) and is more than double the historical peak concentration for (total) 12DCE in this well (53.5 µg/L in July 1988). Concentrations of benzene, 11DCE, and VC in the groundwater samples collected from the well during CY 2002 also exceed respective MCLs (Table 15), with the 11DCE and VC concentrations being substantially higher than indicated by historical data. For instance, no VOCs were detected in the groundwater sample collected from the well in September 1995, which is the last time the well was sampled before March 2002. However, the difference between the CY 2002 and historical VOC results may be an artifact of the change to low-flow sampling. Thus, it is not clear if the CY 2002 monitoring data indicate any significant change in the relative flux of VOCs via the groundwater flowpaths in the Maynardville Limestone that are monitored by well GW-229.

As in previous years, TCE and c12DCE were detected in the groundwater samples collected during CY 2002 from Exit Pathway Picket B wells GW-703, GW-704 (which also contained 11DCE), and GW-706. The types and concentrations of VOCs detected in these wells reflect a combination of strike-parallel transport in the Maynardville Limestone from source areas in the upper reaches of Bear Creek (i.e., the Rust Spoil Area) and inflow of VOC-contaminated groundwater via the flowpaths associated with the losing reach of Bear Creek south of the Oil Landfarm WMA (DOE 1997a). Monitoring results obtained during CY 2002 show that TCE concentrations in each well remain above the MCL (Table 15), with the highest summed VOC concentrations in the deeper groundwater at well GW-704 (53 μ g/L) and the lowest summed VOC concentrations in the shallower groundwater at wells GW-703 (22 μ g/L) and GW-706 (31 μ g/L). As

illustrated by results for TCE, the CY 2002 VOC data for wells GW-703 and GW-704 continue the slightly decreasing long-term concentration trends indicated by respective historical (conventional sampling and low-flow sampling) data for each well (Figure A.30). Although the CY 2002 monitoring results show that the concentrations of TCE detected in the groundwater samples collected from well GW-706 in January (17 $\mu g/L$) and July 2002 (16 $\mu g/L$) are slightly lower than the maximum TCE level evident during CY 2001 (20 $\mu g/L$ in January 2001), they exceed the TCE levels evident in the well during the early 1990s (e.g., 3 $\mu g/L$ in June 1991) and continue a generally increasing concentration trend (see Section 5.1).

3.1.2.3 Radioactivity

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As shown below in Table 16, elevated gross alpha activity (>15 pCi/L) and/or gross beta activity (>50 pCi/L) were reported only for the groundwater samples collected during CY 2002 from nine of the monitoring wells that are completed in the geologic formations which comprise the aquifer in the Bear Creek Regime (listed in sequence from hydraulically upgradient [east] to hydraulically downgradient [west] in the aquifer).

Table 16. Bear Creek Regime CY 2002: elevated gross alpha activity and gross beta activity in surveillance monitoring aquifer wells

*** 11	Date	Gross	Alpha Ac	(pCi/L)	Gro	Gross Beta Activity (pCi/L)			
Well	Sampled	MDA Activity ± CE			MDA		Activit	ty ± CE	
GW-736	03/06/02	5.7	24	±	7.6	7.9	68	±	9.2
GW-738	01/30/02	2.6		<mda< td=""><td>1</td><td>9.1</td><td>57</td><td>±</td><td>8.5</td></mda<>	1	9.1	57	±	8.5
GW-738	07/23/02	3.7		<		10	55	±	9.1
GW-229	03/19/02	1.2	110	±	14	9.8	84	±	10
GW-229	08/12/02	24	73	±	30	73	87	±	48
GW-694	01/29/02	3	22	±	5.1	8.5		<	
GW-703	01/15/02	3.5		<		9.3	62	±	8.9
GW-703	07/15/02	2.5		<		7.3	62	±	8.2
GW-706	01/16/02	3.9	58	\pm	9	6.8	140	±	11
GW-706	07/16/02	2.1	45	\pm	7.8	6.9	72	±	7.5
GW-061	03/12/02	0.89	37	\pm	6.9	6.3	63	±	7.5
GW-061	08/05/02	3.4	42	±	8.7	8.9	73	±	9.3
GW-683	01/14/02	0.81	20	\pm	4.9	7.4		<	
GW-683	07/09/02	0.78	15	\pm	4.2	7.7		<	
GW-684	01/14/02	3.4	23	\pm	5.6	11		<	
GW-684	07/09/02	4.1	17	±	4.9	7.3		<	
Screening	g Level		15 pCi/L				50	pCi/L	

Note: "<" = Less than or equal to screening level

As noted in Section 2.5.1.4, uranium isotopes (and the associated decay products) and Tc-99 are the principal sources of alpha and beta radioactivity, resepctively, in the aquifer in the Bear Creek Regime. The overall distribution of elevated alpha radioactivity in the aquifer reflects the influx of uranium isotopes (and decay products) from several sources via multiple transport pathways. Much of this inflow occurs from a buried northern tributary of Bear Creek that extends beneath the former S-3 Ponds, the catchment of NT-3 west of the former Boneyard/Burnyard, and the tributary catchments to the east (NT-6) and west (NT-7 and NT-8) of BG-A North and BG-A South (DOE 1997a). Moreover, before the CERCLA remedial action at the

Boneyard/Burnyard, uranium isotopes leached from the radiological wastes that were below the saturated zone moved directly into the Maynardville Limestone (DOE 1997a). At some of these sites, particularly the former Boneyard/Burnyard, uranium decay products (e.g., Th-234) are a primary source of beta radioactivity in the groundwater. Elsewhere in the aquifer, however, Tc-99 is the principal beta-emitting radionuclide in the groundwater. The contaminant plume emplaced during operation of the former S-3 Ponds is the only known source of Tc-99 in the Bear Creek Regime and the distribution of Tc-99 generally mirrors that of nitrate in the aquifer, reflecting both their common source and their high mobility in the groundwater system.

Elevated levels of gross alpha activity (24 pCi/L) and gross beta activity (68 pCi/L) were reported for the groundwater sample collected from Exit Pathway Picket C well GW-736 in March 2002; however, in July 2002, neither radiological analyte exceeded the respective MDA. Historical data for this well, which was not sampled between September 1995 and March 2002, show much lower gross alpha activity, with the highest activity reported for the sample collected from the well in August 1992 (7.82 pCi/L). However, the result for gross beta activity is comparable to historical levels of gross beta activity, which last exceeded the SDWA screening level in December 1993 (52 pCi/L). The alpha- and beta-emitting radionuclides in this well have not been conclusively identified because none of the groundwater samples from the well have been analyzed for radioisotopes. Nevertheless, the elevated alpha and beta radioactivity in the groundwater at this well is probably from uranium isotopes (and associated decay products) and Tc-99, respectively, transported from the contaminant plume emplaced during operation of the former S-3 Ponds (DOE 1997a). Considering the long gap in the sampling history for the well and the inherent variability commonly associated with the analytical results for gross alpha and gross beta activity, the CY 2002 monitoring results do not suggest any clear increase or decrease in the relative flux of alpha- and beta-emitting radionuclides via the groundwater flowpaths in the Maynardville Limestone that are monitored by the well.

The CY 2002 monitoring results show elevated beta radioactivity in the Maynardville Limestone at Exit Pathway Picket C well GW-738 (Table 16). Historical data for the well indicate that the beta radioactivity in the groundwater at this well may be attributable primarily to Tc-99, which was detected (i.e., Tc-99 activity >MDA and CE) in the groundwater samples collected from the well during January 2001 (81 pCi/L) and July 2001 (65 pCi/L). Also, the gross beta results obtained during CY 2002 continue a fairly indeterminate long-term trend characterized by cyclical (seasonal) fluctuations, as illustrated by the gross beta results reported for the groundwater samples collected from the well in March 1994 (48.3 pCi/L), August 1996 (22.2 pCi/L), March 1998 (47 pCi/L), July 2000 (32 pCi/L), and January 2002 (57 pCi/L). This trend suggests seasonally variable flux of Tc-99 via the flowpaths in the Maynardville Limestone that are monitored by well GW-738.

Monitoring results obtained during CY 2002 show higher levels of alpha and beta radioactivity in the groundwater at well GW-229 than evident upgradient of the well in the groundwater at the Exit Pathway Picket C wells (Table 16). Elevated alpha and beta radioactivity in the groundwater at well GW-229 reflects the influx of uranium isotopes (and associated decay products) leached from the radiological wastes at the former Boneyard/Burnyard that were below the saturated zone, which enter the Maynardville Limestone downgradient of Exit Pathway Picket C (DOE 1997a). Also, the gross alpha and gross beta activities reported for the groundwater samples collected from the well during CY 2002 are substantially higher than indicated by historical data, as illustrated by the gross alpha and gross beta activities reported for the groundwater samples collected from the well in February 1990 (5.8 pCi/L and 9.8 pCi/L, respectively), September 1995 (6 pCi/L and 11 pCi/L, respectively), and March 2002 (110 pCi/L and 84 pCi/L, respectively). The difference between the CY 2002 and historical radiological data for this well may be an artifact of the change to low-flow sampling. Thus, it is not clear if the CY 2002 gross alpha and gross beta results for well GW-229 indicate increasing long-term trends and corresponding increases in the relative flux of uranium isotopes (and

associated decay products) via the groundwater flowpaths in the Maynardville Limestone that are monitored by the well.

Gross alpha activity at or slightly above the MCL was reported for the groundwater sample collected from Exit Pathway Picket B well GW-694 in January 2002 (22 pCi/L) and July 2002 (15 pCi/L). Although none of the groundwater samples from this well have been analyzed for uranium isotopes, the elevated concentrations of total uranium in the well (see Section 3.1.2.1) suggest that the alpha radioactivity is primarily from uranium isotopes. The presence of uranium isotopes in the groundwater at this well (and the elevated alpha radioactivity) is believed to reflect influx of contaminated groundwater (and surface water) from the NT-3 catchment (DOE 1997a), which enters Bear Creek about 3,500 ft upstream of Exit Pathway Picket B (Figure A.2). The CY 2002 monitoring results also show that alpha radioactivity in the well is generally lower than previously evident, although the results for gross alpha activity reflect wide short-term fluctuations that tend to dominate what appears to be a generally decreasing long-term trend (Figure A.31).

As shown in Table 16, elevated gross beta activity was the reported for both groundwater samples collected from Exit Pathway Picket B well GW-703 during CY 2002. Results of radiological analyses demonstrate that the beta activity in the well is from Tc-99, which was detected in the groundwater samples collected from the well in January 2001 (54 pCi/L), July 2001 (65 pCi/L), January 2002 (66 pCi/L), and July 2002 (62 pCi/L). Also, the gross beta results obtained during CY 2002 generally continue the widely fluctuating but apparently increasing long-term trend for gross beta activity in the well. A similarly increasing trend for gross beta activity also is indicated by the data for Exit Pathway Picket B well GW-695, although gross beta activity reported for the groundwater samples collected from this well during CY 2002 did not exceed the SDWA screening level. Section 5.1 provides an evaluation of the relative significance of these increasing trends.

The gross alpha activity results reported for each of the groundwater samples collected from Exit Pathway Picket B well GW-706 during CY 2002 exceed the MCL (Table 16). Results of radiological analyses show that uranium isotopes are the primary source of the alpha activity in groundwater at this well, with the highest U-234 activity (21.89 pCi/L) and U-238 activity (45.9 pCi/L) reported for the sample collected in January 2002. Similar levels of U-234 and U-238 were detected in the groundwater samples collected from this well during CY 2001. The uranium isotopes in the groundwater at this well probably originated from the former Boneyard/Burnyard, where uranium from the radiological wastes that were below the saturated zone leached directly into the Maynardville Limestone about 3,500 ft east-northeast (hydraulically upgradient) of the well (DOE 1997a). Also, the CY 2002 results for gross alpha activity continue the indeterminate long-term trend indicated by historical data for the well, as illustrated by the gross alpha results reported for the groundwater samples collected from the well in August 1996 (62.8 pCi/L), January 1998 (42 pCi/L), July 2000 (54 pCi/L), and January 2002 (58 pCi/L).

In addition to elevated gross alpha activity, the groundwater samples collected from well GW-706 during CY 2002 contained gross beta activity above the SDWA screening level (Table 16). The elevated beta radioactivity in the groundwater at this well reflects commingling of Tc-99 from the former S-3 Ponds and uranium decay products (e.g., Th-234) from the former Boneyard/Burnyard (DOE 1997a). This is supported by the monitoring results obtained during CY 2002; Tc-99 was detected in the groundwater samples collected from the well in January 2002 (160 pCi/L) and July 2002 (57 pCi/L), and the results of the isotopic uranium analyses suggest (assuming secular equilibrium with U-238) Th-234 activities of 46 pCi/L in January 2002 and 33 pCi/L in July 2002 Compared to historical data for the well, the CY 2002 results for gross beta activity continue an indeterminate long-term trend that is skewed upward by the atypically high value reported for the sample collected in January 2001 (310 pCi/L), which is the highest gross beta activity reported for the well.

Elevated levels of gross alpha and gross beta activity were reported for the groundwater samples collected from well GW-061 during CY 2002 (Table 16), with the highest values reported for the groundwater sample collected from the well in August 2002 (seasonally low-flow conditions). These results are consistent with historical data for this well, which show sporadically elevated levels of alpha and beta radioactivity, including the results for gross alpha activity (20 pCi/L) and gross beta activity (56 pCi/L) evident when the well was previously sampled in September 1995. The CY 2002 monitoring results for gross alpha activity also continue the generally increasing trend indicated by historical data for the well (see Section 5.1); results for gross beta activity reflect an indeterminate long-term trend, as illustrated by the gross beta results reported for the groundwater samples collected from the well in September 1991 (82 pCi/L), September 1994 (71 pCi/L), and August 2002 (73 pCi/L).

Gross alpha activity equal to or greater than the MCL was reported for each of the groundwater samples collected from Exit Pathway Picket A wells GW-683 and GW-684 during CY 2002 (Table 16). Elevated gross alpha activity in the groundwater at both of these wells probably reflects the migration of uranium isotopes into successively higher hydrostratigraphic zones in the Maynardville Limestone and ultimately into the lower Copper Ridge Dolomite (DOE 1997a). This interpretation is supported by results of isotopic analyses performed during CY 2001, which show relatively low levels of U-234 (6.3 to 9.7 pCi/L) and U-238 (12 to 18 pCi/L) in these wells. Monitoring results obtained during CY 2002 also continue the widely variable, indeterminate or slightly decreasing trends indicated by historical data for each well, as illustrated by the gross alpha activity reported for the groundwater samples collected from well GW-683 in September 1991 (27.8 pCi/L), August 1995 (25 pCi/L), and July 2002 (15 pCi/L).

3.2 EAST FORK REGIME

The CY 2002 monitoring results reported for a total of 32 monitoring wells in the East Fork Regime were evaluated to meet surveillance monitoring requirements of DOE Order 5400.1 (Table B.2). As shown on Figure A.3, 14 of the wells are completed in the geologic formations comprising the aquitard and 18 of the wells are completed in the aquifer (Maynardville Limestone). Respective evaluations of the monitoring data for the aquitard wells and aquifer wells are provided in the following sections.

3.2.1 Aguitard Monitoring Wells

As shown in Table 17, elevated concentrations of one or more of the principal groundwater contaminants in the East Fork Regime were reported for at least one of the groundwater samples collected during CY 2002 from 12 of the surveillance monitoring aquitard wells.

Table 17. East Fork Regime CY 2002: principal contaminants detected in surveillance monitoring aquitard wells

	Monitored	Inoi	ganics	TIO G	Radioactivity		
Well	Interval Depth (ft bgs)	Nitrate	Uranium	VOCs	Alpha Activity	Beta Activity	
GW-108	41.0 - 58.6	•		•	•	•	
GW-204	6.5 - 17.3		•		•		
GW-383	16.6 - 23.6			•			
GW-633	3.5 - 15.0	•		•		•	
GW-658	6.9 - 19.1			•			
GW-762	46.4 - 58.7			•			
GW-763	4.0 - 16.0			•			
GW-769	48.2 - 60.3			•			
GW-770	7.5 - 19.0			•			
GW-775	45.0 - 56.4			•			
GW-782	23.8 - 35.9			•	•		
GW-791	57.5 70.6	•		•			
Scre	ening Level	10 mg/L	0.03 mg/L	5μg/L	15 pCi/L	50 pCi/L	

The following sections provide separate discussions of the CY 2002 monitoring results for each major type of contaminant (inorganics, VOCs, and radioactivity).

3.2.1.1 Inorganic Contaminants

As shown below in Table 18, elevated concentrations of nitrate or uranium were detected in the groundwater samples collected during CY 2002 from aquitard wells GW-108 and GW-633 in the western Y-12 area and well GW-204 in the central Y-12 area.

Table 18. East Fork Regime CY 2002: elevated nitrate and uranium concentrations in surveillance monitoring aquitard wells

		Nitrate	(mg/L)	Uranium (mg/L)				
Well Location/Number	1st/2nd (2002	-	3rd/4th Qtr. 2002	1st/2nd Qtr. 2002	3rd/4th Qtr. 2002			
Western Y-12 Area GW-GW-	· · · · · · · · · · · · · · · · · · ·	,520 ,360	1,510 9,280	< <	< <			
Central Y-12 Area GW-	204	<		0.0439	0.0336			
MCL		10 n	ng/L	0.03 mg/L				
Note: "." = Not detected; "<"	Note: "." = Not detected; "<" = Less than MCL							

Well GW-633 is located directly south of the Rust Garage Area about 720 ft east (parallel with geologic strike) of the southeast corner of the former S-3 Ponds (Figure A.3). Installed during April 1990 as part of an investigation of petroleum fuel USTs at the Rust Garage Area, this well is completed at a shallow depth (15 ft bgs) in the Nolichucky Shale (water table interval) and has a proportionally long (10 ft) screened interval intended to straddle the water table and facilitate detection of immiscible petroleum products. Last sampled in October 2000, this well yields acidic (pH <6), highly mineralized (TDS >9,000 mg/L) calcium-

magnesium-bicarbonate groundwater distinguished by very high concentrations of nitrate (>1,000 mg/L) and other components of the Eastern S-3 Ponds Plume (the contaminant plume emplaced during operation of the former S-3 Ponds that extends eastward into the East Fork Regime). In this area, the Eastern S-3 Ponds Plume has intermingled with groundwater contaminant plumes from other sources in the western Y-12 area, including a plume of petroleum hydrocarbons that originates from former diesel and gasoline USTs at the Rust Garage Area (DOE 1998). Monitoring results obtained during CY 2002 show that nitrate levels in the shallow groundwater at well GW-633 remain above 1,000 mg/L (Table 18), but are about 20% lower than evident in October 2000 (1,890 mg/L). These nitrate results also indicate substantially lower concentrations than evident in the well during the early 1990s (e.g., 5,501 mg/L in September 1993). However, the lower nitrate levels may be an artifact of the change to low-flow sampling (Table 4). Nevertheless, separate plots of the conventional sampling and low-flow sampling data both indicate generally decreasing concentration trends (Figure A.32). Decreasing concentrations of nitrate in the shallow groundwater at well GW-633 suggest that the center of mass of the Eastern S-3 Ponds Plume in the Nolichucky Shale lies to the east of the well (DOE 1998).

Well GW-108 is part of a three-well cluster in the Nolichucky Shale about 125 ft southeast of well GW-633 (Figure A.3). Completed at a depth of about 59 ft bgs (shallow bedrock interval), well GW-108 is believed to monitor some of the primary strike-parallel migration pathways for components of the Eastern S-3 Ponds Plume (DOE 1998). This well yields extremely mineralized (TDS >50,000 mg/L) and acidic (pH <6) groundwater distinguished by very high levels of nitrate (and other inorganic contaminants), and the CY 2002 monitoring results show that nitrate levels in the well remain above 9,000 mg/L (Table 18). These results continue the generally decreasing nitrate concentration trend indicated by historical data for the well (Figure A.33), with the nitrate level evident in July 2002 (9,280 mg/L) being the lowest detected in the well since January 2000 (8,980 mg/L). Decreasing concentrations of nitrate in the groundwater at well GW-108 are believed to reflect: (1) the substantially reduced flux of nitrate after closure of the S-3 Ponds and installation of the low-permeability cap; (2) continued eastward (strike-parallel) migration of the center of mass of the Eastern S-3 Ponds Plume; and (3) differential retardation and natural attenuation in the subsurface; and (4) upward discharge into the surface water flow system (DOE 1998).

Located on the east side of Building 9204-2 (Figure A.3), well GW-204 is a shallow well (17.5 ft bgs) that was installed into the pit from which a petroleum fuel UST (Tank 0134-U) was excavated and removed in August 1988. The former tank pit is within the subcrop area of the Nolichucky Shale about 350 ft directly north (across geologic strike) of the contact with the Maynardville Limestone. This well yields calcium-magnesium-bicarbonate groundwater distinguished by elevated (total) uranium concentrations; the specific source of the uranium has not been determined, but may be associated with Building 9204-2 (DOE 1998). Groundwater monitoring results obtained during CY 2002 show that uranium concentrations in the well remain above the MCL (Table 18), with the highest concentration (0.0439 mg/L) reported for the groundwater sample collected from the well in May 2002 (i.e., seasonally high flow conditions). These results continue the indeterminate long-term concentration trend indicated by historical uranium data for the well, as illustrated by the similar levels of uranium evident in November 1992 (0.036 mg/L) and November 2002 (0.0336 mg/L).

3.2.1.2 Volatile Organic Compounds

One or more dissolved VOCs were detected at individual or summed concentrations of $5 \mu g/L$ or more in at least one groundwater sample collected during CY 2002 from 11 of the surveillance monitoring aquitard wells in the East Fork Regime. Summed concentrations of the VOCs detected in these wells range from less than

 $10 \,\mu\text{g/L}$ (GW-770 and GW-775) to more than 1,000 $\mu\text{g/L}$ (GW-658 and GW-762). As shown in Table 19, the maximum concentrations of PCE, TCE, c12DCE, 11DCE, VC, 12DCA, CTET, MC, benzene, ethylbenzene (ETB), and toluene reported for at least one of these wells exceed respective MCLs.

Table 19. East Fork Regime CY 2002: maximum VOC concentrations in surveillance monitoring aquitard wells

				Maxi	mum C	oncent	ration (µ	ıg/L)			
Well Location/Number	PCE	TCE	c12 DCE	11 DCE	VC	12 DCA	CTET	MC	Ben- zene	ЕТВ	Tolu- ene
Western Y-12 Area GW-633 GW-108	180	8 <	< .	< .				36 69	850	· ·	< .
Central Y-12 Area GW-769 GW-770 GW-775 GW-782 GW-791	22 170 650	6 6 60 <	<	48	2		160 7	7			
Eastern Y-12 Area GW-383 GW-658 GW-762 GW-763	400 2,400 43	200 150 10	140 70 130	< 44 <	2 4 10	570			8,700	1,400	4,900
MCL (μg/L) Note: "." = Not detected; "<	5 <" = Les:	5 s than M	70 ICL	7	2	5	5	5	5	700	1,000

The CY 2002 monitoring results for these wells are described in sequence from hydraulically upgradient (west and north) to downgradient (east and south) in the East Fork Regime.

As noted in Section 3.2.1.1, the highly mineralized, nitrate-contaminated groundwater in well GW-633 contains a mixture of dissolved chlorinated solvents and petroleum hydrocarbons (benzene, ETB, toluene, and dimethylbenzene [DMB]). The former S-3 Ponds and other former waste management sites within the Y-12 Salvage Yard are the suspected sources of the chlorinated solvents in the well; leaks and/or spills during historical operations of diesel and gasoline USTs in the Rust Garage Area, which were excavated and removed in 1988 and 1989, are the source of the petroleum hydrocarbons in the well (DOE 1998). Monitoring results for each of the compounds detected in the groundwater samples collected from the well during CY 2002 are consistent with the previous low-flow sampling results obtained during CY 2000, but as shown below in Table 20, the low-flow sampling results for some compounds, particularly PCE and benzene, differ substantially from respective historical conventional sampling data.

Table 20. Selected VOC results for well GW-633

	Concentration (µg/L)									
VOC	(Convention	al Samplir	ıg	Low-Flow Sampling					
, 00	Sept. 1991	March 1992	Nov. 1993	March 1994	June 2000	Oct. 2000	April 2002	Oct. 2002		
PCE	64	91	30	57	200	170	180	170		
TCE	8	11	2 J	4 J	9	8	8	6		
12DCE (total)	2 J				7	11	10	10		
11DCE	0.8 J		0.8 J	1 J	•		3 J			
Chloroform	24	40	6	12	26	24	20	17		
MC	FP	FP	FP	FP	35	38	36	27		
Benzene	2 J	3 J	4 J	6	650	560	840	850		
ETB					34	26	20	8		
Toluene	1 J	3 J	4 J	5	150	55	4 J	2 J		
DMB			3 J		250	190	110	95		

Note: "." = Not detected; FP = False positive results; J = Estimated concentration

Assuming a fairly heterogeneous mixture of dissolved VOCs in the groundwater, it is not clear from the available data how the conventional or low-flow sampling method would influence the concentrations of some compounds and not others. Moreover, it is not clear if the increasing long-term concentration trends indicated by the conventional and low-flow sampling results for PCE and benzene are artifacts of the sampling method, with higher concentrations of both compounds evident in samples obtained with the latter method (see Section 5.2). Conversely, the CY 2002 monitoring results for other compounds reflect more indeterminate or decreasing concentration trends that do not exhibit any clear response to the change in the groundwater sampling method, as illustrated by the TCE and 11DCE results summarized in Table 20.

Nitrate-contaminated groundwater in the Nolichucky Shale (shallow bedrock interval) at well GW-108 contains a mixture of dissolved VOCs dominated by chloroform and MC, along with low levels ($<5 \,\mu g/L$) of bromoform, PCE, and TCE. Each compound was detected in at least one of the groundwater samples collected from the well during CY 2002, with the highest concentration evident for MC (69 $\mu g/L$), which exceeds the MCL (Table 19), and the lowest concentrations evident for PCE (1 $\mu g/L$) and TCE (2 $\mu g/L$). Compared to other components of the Eastern S-3 Ponds Plume (e.g., nitrate), the relatively low concentrations of VOCs in the shallow groundwater at well GW-108 primarily reflects the substantially smaller volume of organic wastes disposed at the site (DOE 1998). Also, the CY 2002 monitoring continue the fairly indeterminate long-term concentration trend indicated by historical VOC data for the well, as illustrated by the chloroform concentrations detected in the groundwater samples collected from the well in March 1997 (29 $\mu g/L$), February 1999 (38 $\mu g/L$), and January 2002 (29 $\mu g/L$).

Located south of Building 9212 in the northern part of the central Y-12 area (Figure A.3), well GW-791 is completed at a depth of 70 ft bgs in the Maryville Limestone (shallow bedrock interval). This well yields calcium-magnesium-bicarbonate groundwater with historical data showing very high concentrations of PCE (e.g., $2,100~\mu g/L$ in April 1997) that potentially reflect the (nearby) presence of DNAPL from a source associated with the production complex in the vicinity of Building 9212 (DOE 1998). Groundwater monitoring results obtained during CY 2002 show that PCE levels in the well remain substantially above the MCL (Table 19), with the PCE concentration detected in the groundwater sample collected in

November 2002 (650 μ g/L) being the highest level evident in any sample collected since October 2000 (730 μ g/L). Aside from PCE, only low (estimated) levels of TCE were detected in the groundwater samples collected from the well during CY 2002, which is consistent with historical data showing a consistent lack of PCE degradation products in the groundwater at this well. This suggests little if any biodegradation of the PCE; results of microbiologic analyses of a groundwater sample collected from the well in May 2000 show minimal microbial activity in the groundwater at this well (BWXT 2001b). Also, the PCE concentrations in the groundwater samples from this well are strongly influenced by the sampling method, with substantially higher PCE levels evident in samples obtained with the conventional sampling method (BWXT 2001b). Plotted separately (Figure A.34), the conventional sampling data show a generally decreasing PCE concentration trend, but the low-flow sampling results show a more indeterminate trend dominated by wide temporal fluctuations, with an increasing trend indicated by the PCE levels evident in October 2000 (21 μ g/L), October 2001 (100 μ g/L), and November 2002 (650 μ g/L).

Well GW-782 is completed at a depth of 36 ft bgs in the upper Nolichucky Shale (water table interval) near the southwest corner of Building 9731, approximately 1,000 ft southeast of well GW-791 (Figure A.3). Historical data show that well GW-782 monitors calcium-magnesium-bicarbonate groundwater containing a mixture of dissolved VOCs that are believed to originate from one or more sources in the vicinity of Building 9204-2 and Building 9731 (DOE 1998). Maximum concentrations of the VOCs detected in the samples collected from the well during CY 2002 show that PCE (170 μ g/L) and 11DCA (180 μ g/L) remain the primary compounds in the well and that the concentrations of TCE, 11DCE, and VC remain at or above respective MCLs (Table 19). Biotic degradation of PCE and 11DCA potentially account for the suite of compounds in the groundwater at this well because, as shown in the following data summary (Table 21), results for several indicator parameters suggest favorable geochemical conditions.

Table 21. Geochemical indicators for biodegradation of chlorinated solvents in well GW-782

Geochemical Parameter/ Optimum Range (Wilson <u>et al</u> . 1996)	April 2001	September 2001	May 2002	November 2002
Nitrate < 1 mg/L Iron (II) > 1 mg/L Sulfate < 20 mg/L REDOX < 50 mV pH 5 < pH < 9	0.175 0.96* 18.4 147** 7.12**	0.081 0.772* 17.9 33** 7.08**	<0.02 1.08* 16.8 28** 7.04**	<0.02 1.35* 15.4 -44** 7.33**
Note: *Results are for total iron; **Field	measurement.	1		1

The CY 2002 monitoring results for well GW-782 also continue the relatively indeterminate long-term concentration trend indicated by historical VOC data for the well, as illustrated by the PCE concentrations detected in the groundwater samples collected in June 1995 (180 μ g/L), November 1997 (200 μ g/L), October 1999 (170 μ g/L), September 2001 (200 μ g/L), and November 2002 (160 μ g/L).

Wells GW-769 (60 ft bgs) and GW-770 (19 ft bgs) are clustered in the Nolichucky Shale (shallow bedrock interval and water table interval, respectively) near the northeast corner of Building 9201-2, about 2,160 ft east (parallel with geologic strike) of well GW-782 (Figure A.3). The wells yield calcium-magnesium-bicarbonate groundwater containing a mixture of dissolved chloroethenes (PCE, TCE, and c12DCE) and chloromethanes (CTET and chloroform), with the highest summed VOC concentrations typically evident in the deeper groundwater at well GW-769. The source(s) of the VOCs in the groundwater at these wells may be associated with Buildings 9202, 9203, and 9205 where large amounts of CTET were used to convert

uranium trioxide to uranium tetrachloride (DOE 1998). Analytical results for the chloroethenes detected in the groundwater samples collected from well GW-769 during CY 2002 are consistent with historical results and continue an increasing long-term concentration trend; the CY 2002 results for CTET also continue a strongly increasing concentration trend indicated by historical data (see Section 5.2). In contrast, the CY 2002 monitoring results for well GW-770 show only low levels ($<10~\mu g/L$) of CTET and chloroform. These results continue the indeterminate long-term concentration trends indicated by historical data for this well, as illustrated by the chloroform concentrations evident in November 1993 (9 $\mu g/L$), November 1995 (4 $\mu g/L$), November 1997 (4 $\mu g/L$), October 1999 (7 $\mu g/L$), October 2001 (8 $\mu g/L$), and October 2002 (3 $\mu g/L$).

Wells GW-775 and GW-776 are clustered in the Nolichucky Shale about 1,000 ft east-southeast (parallel with geologic strike) of wells GW-769 and GW-770 (Figure A.3). Completed at depths of 56 ft bgs (shallow bedrock interval) and 23 ft bgs (water table interval), respectively, wells GW-775 and GW-776 were last sampled in October 1999 and the respective historical monitoring results show that these wells yield chloride-and sulfate-enriched calcium-magnesium-bicarbonate groundwater containing low levels ($<10\,\mu\text{g/L}$) of TCE (GW-775 and GW-776) and PCE (GW-776). Monitoring results obtained during CY 2002 show low concentrations of PCE in well GW-776 ($2\,\mu\text{g/L}$ in October 2002) along with similarly low levels of TCE in well GW-775, although the TCE concentration detected in the groundwater sample collected from this well in October 2002 ($6\,\mu\text{g/L}$) slightly exceeds the MCL (Table 19). The CY 2002 monitoring results for wells GW-775 and GW-776 are consistent with respective historical VOC data, which indicate fairly indeterminate long-term concentration trends for each well, as illustrated by the TCE levels detected in the groundwater samples collected from well GW-775 in April 1993 ($3\,\mu\text{g/L}$), May 1995 ($5\,\mu\text{g/L}$), May 1997 ($5\,\mu\text{g/L}$), April 1999 ($5\,\mu\text{g/L}$), and April 2002 ($4\,\mu\text{g/L}$).

Well GW-658 is located near the Building 9754-2 Fuel Facility, about 785 ft northeast of wells GW-775 and GW-776 (Figure A.3). This well was installed in August 1990 as part of an investigation of the Garage Underground Tanks, which included four USTs that served for many years to store petroleum fuel (gasoline and diesel), spent solvents, and used oil before they were excavated and removed in 1989 (DOE 1998). Well GW-658 is completed at a shallow depth (19 ft bgs) in the Nolichucky Shale (water table interval) and has a proportionally long (10 ft) screened interval intended to straddle the water table and facilitate detection of any immiscible petroleum products in the groundwater. Last sampled in August 1998, the historical data show that the calcium-magnesium-bicarbonate groundwater in the well, which is clearly distinguished by unusually high (>20 mg/L) concentrations of iron and manganese, contains a mixture of 12DCA and petroleum hydrocarbons. As shown below in Table 22, the groundwater monitoring results obtained during CY 2002 indicate 12DCA above 500 μ g/L and summed concentrations of benzene, ETB, toluene, and DMB that exceed 20,000 μ g/L.

Table 22. Selected VOC results for well GW-658

	Concentration (µg/L)									
voc		Convention	nal Sampling	Low-Flow Sampling						
	Mar. 1991	Dec. 1991	Mar. 1993	Nov. 1993	Aug. 1998	Apr. 2002	Oct. 2002			
12DCA		940	560	370	1,100	570				
Benzene	4,300	10,000	10,000	4,800	15,000	7,800	8,700			
ETB	300	710	1,100	760	1,800	920	1,400			
Toluene	900	2,200	5,700	3,400	10,000	4,800	4,900			
DMB	2,600	4,100	6,800	4,000	NA	8,800	8,800			
Note: "." = Not	Note: "." = Not detected; NA = Not analyzed									

These VOC results demonstrate little, if any, difference between conventional sampling and low-flow sampling data for the well and illustrate indeterminate long-term concentration trends dominated by wide short-term concentration variations. Moreover, the very high levels of dissolved petroleum hydrocarbons evident during CY 2002 show that residual petroleum hydrocarbons remain in the subsurface more than ten years after the removal of the USTs in CY 1989. Concentrations of VOCs also remain very high because the anaerobic conditions in the shallow groundwater at this well (field measurements during sampling in March and August 2002 did not detect any dissolved oxygen in the groundwater purged from the well) would inhibit biotic degradation of the petroleum hydrocarbons.

Wells GW-762 and GW-763 are clustered in the upper Nolichucky Shale about 1,200 ft southeast (across geologic strike) of well GW-658 (Figure A.3). Both wells monitor calcium-magnesium-bicarbonate groundwater containing a mixture of dissolved VOCs that are believed to originate from DNAPL in the subsurface near Building 9720-6 (DOE 1998). Historical monitoring data show that PCE and its associated degradation products (primarily 12DCE) are the principal compounds in the groundwater at both wells. Additionally, summed concentrations of VOCs in well GW-762 (>1,000 μ g/L), which is completed at a depth of about 60 ft bgs (shallow bedrock interval), are at least an order-of-magnitude higher than the summed concentrations of VOCs in well GW-763 (>100 μ g/L), which is completed at a depth of only 16 ft bgs (water table interval). Monitoring results obtained during CY 2002 show that VOC concentrations remain very high in the groundwater at well GW-762, with summed concentrations above 2,000 μ g/L and respective maximum levels of PCE, TCE, 11DCE, and VC that exceed corresponding MCLs (Table 19). These VOC results also continue the fluctuating but generally increasing long-term concentration trend indicated by historical data for well GW-762 (see Section 5.2).

As in previous years, the groundwater samples collected from well GW-763 during CY 2002 contained substantially lower summed VOC concentrations compared to well GW-762, although the concentrations of c12DCE in well GW-763 were higher than evident in well GW-762 (Table 19). Because the presampling groundwater elevations in these wells indicate downward vertical hydraulic gradients, the difference between the VOC concentrations in wells GW-762 and GW-763 may be attributable to dilution from greater recharge to the water table interval (GW-763) relative to the shallow bedrock interval (GW-762) in the Nolichucky Shale. Also, the higher concentrations of c12DCE relative to PCE in well GW-763 suggests more efficient biotic degradation in the shallower flow system. This is supported by results for several indicator parameters, including very low REDOX (e.g., -173 mV in October 2002), which suggest that the geochemical conditions in the shallow groundwater at well GW-763 are more favorable to biodegradation than are the geochemical conditions evident in the deeper groundwater at well GW-762. Nevertheless, the summed concentrations of VOCs detected in the groundwater samples collected from well GW-763 in June 2002 (127 µg/L) and October 2002 (197 µg/L) are substantially higher than summed VOC concentrations evident for all the other groundwater samples obtained from this well with the low-flow sampling method (e.g., 6 µg/L in December 1998), except one sample collected in October 2000 (138 µg/L) as part of the evaluation of the conventional and low flow sampling methods. The higher concentrations are probably related to the redevelopment of the well in April 2002, when GWPP personnel bailed approximately five well volumes of groundwater from the well. The apparent increase in the concentration of VOCs following the redevelopment of the well is consistent with the results of the sampling method evaluation performed in CY 2000, which showed higher VOC concentrations in the sample that was obtained with the low-flow sampling method six months after (October 2000) the well had been purged (three well volumes) for conventional sampling in May 2000 (BWXT 2001b). This sensitivity to the sampling method imparts significant uncertainty to the relative significance of the long-term concentration trends indicated by the VOC results for well GW-763.

The DNAPL believed to be present in the subsurface near Building 9720-6 is the suspected source of the dissolved chloroethenes in the shallow (<25 ft bgs) groundwater at well GW-383 (DOE 1998), which is about

350 ft east-northeast of wells GW-762 and GW-763 (Figure A.3). Completed in the Nolichucky Shale (water table interval), well GW-383 is believed to monitor groundwater flowpaths on the west side of NHP that are hydraulically connected with the buried former channel of UEFPC (DOE 2002). Historical data show that this well yields chloride-enriched (>50 mg/L) calcium-magnesium-bicarbonate groundwater containing a mixture of dissolved chlorinated solvents, primarily PCE, TCE, and 12DCE, along with low levels (<10 μ g/L) of 11DCE, VC, and CTET. Aside from CTET, each compound was detected in at least one of the groundwater samples collected from the well during CY 2002, with maximum concentrations of PCE (400 μ g/L), TCE (200 μ g/L), and c12DCE (140 μ g/L) being substantially above respective MCLs (Table 19). These results continue the generally increasing concentration trend indicated by historical data for the well (see Section 5.2).

3.2.1.3 Radioactivity

As shown below in Table 23, elevated gross alpha activity (>15 pCi/L) and/or gross beta activity (>50 pCi/L) was reported for groundwater samples collected during CY 2002 from surveillance monitoring aquitard wells located in the western Y-12 area (GW-108 and GW-633) and the central Y-12 area (GW-204 and GW-782).

Table 23. East Fork Regime CY 2002: elevated gross alpha activity and gross beta activity in surveillance monitoring aquitard wells

Well Location/	Date	Gross Alpha Activity (pCi/L)				Gre	Gross Beta Activity (pCi/L)			
Number	Sampled	MDA	Activity ± CE		MDA	Activity ± CE				
Western Y-12 Area										
GW-633	04/23/02	44		<mda< td=""><td></td><td>71</td><td>3,000</td><td>±</td><td>150</td></mda<>		71	3,000	±	150	
GW-633	10/17/02	43		<mda< td=""><td><u>.</u></td><td>71</td><td>3,700</td><td>±</td><td>170</td></mda<>	<u>.</u>	71	3,700	±	170	
GW-108	01/08/02	109.95		<mda< td=""><td></td><td>82.38</td><td>7,954.49</td><td>±</td><td>183.42</td></mda<>		82.38	7,954.49	±	183.42	
GW-108	07/09/02	93.97	146.63	±	97.76	81.55	11,532.61	±	213.59	
Central Y-12 Area										
GW-204	05/02/02	2.2	35	±	6.4	7.9		<mda< td=""><td></td></mda<>		
GW-204	11/06/02	7.2	22	±	6.3	6.8		<		
GW-782	05/01/02	2.5	45	±	7.7	6.7		<		
GW-782	11/04/02	7.3	38	±	7.8	9.7		<		
Screening Le	Screening Level 15 pCi/L 50 pCi/L									
Note: "<" = Exceeds	Note: "<" = Exceeds the MDA, but less than the screening level									

The CY 2002 monitoring results show that beta radioactivity remains very high in the shallow groundwater at wells GW-108 (>10,000 pCi/L) and GW-633 (>3,000 pCi/L). The source of the beta radioactivity in these wells is the Tc-99 within the Eastern S-3 Ponds Plume (the only source of Tc-99 in the East Fork Regime). Analytical results obtained during CY 2002 show that Tc-99 activity in the groundwater at well GW-108 remains nearly an order-of-magnitude above the SDWA threshold level (4,000 pCi/L) for a 4 mrem/yr dose equivalent. Moreover, the Tc-99 activity reported for the groundwater sample collected from the well in January 2002 (29,525 pCi/L) is new maximum value for this well. Groundwater samples collected from well GW-633 during CY 2002 were not analyzed for Tc-99, but historical data show that Tc-99 activity in the well exceeds the SDWA threshold level, as illustrated by the Tc-99 results reported for the groundwater samples collected from the well in June 2000 (6,600 pCi/L) and October 2000 (7,500 pCi/L). Historical data show

a clearly increasing trend for beta radioactivity in well GW-108, which suggests a corresponding increase in the relative flux of Tc-99 along the flowpaths in the Nolichucky Shale that are monitored by the well (see Section 5.2). The CY 2002 results for gross beta activity in well GW-633 are, like the CY 2000 low-flow sampling results for gross beta activity in the well, substantially higher than indicated by historical gross beta results obtained from conventional sampling. Thus, the higher gross beta activity may be an artifact of the sampling method or may reflect a corresponding increase in the relative flux of Tc-99 at some time during the six-year gap (March 1994 - June 2000) in the sampling history for this well. Plotted separately, the conventional sampling (March 1991 - March 1994) results show a widely variable trend for gross beta activity and the low-flow sampling results (June 2000 - October 2002) indicate a decreasing trend for gross beta activity (Figure A.32).

Analytical results obtained during CY 2002 show that the elevated gross alpha activity in the shallow groundwater at well GW-204 remains above the MCL (Table 23). Radiological analyses of the groundwater samples collected from the well during CY 2001 and CY 2002 confirm that the alpha radioactivity is from U-234 and U-238, with the highest activities of these isotopes reported for the samples collected in May 2001 (U-234 = 33 pCi/L and U-238 = 29 pCi/L) and May 2002 (U-234 = 21 pCi/L and U-238 = 16 pCi/L). Considering the relatively limited mobility of uranium isotopes in the groundwater, the source area(s) may be relatively close to the well and may be associated with Building 9204-2 to the west and north of the well (DOE 1998). Along with historical data, the groundwater monitoring results obtained during CY 2002 continue the indeterminate long-term trend for alpha radioactivity in the well, as illustrated by the gross alpha results reported for the groundwater samples collected in September 1991 (22 pCi/L), March 1993 (31 pCi/L), June 2000 (28 pCi/L), and May 2002 (35 pCi/L).

The CY 2002 monitoring results for well GW-782 show that gross alpha activity in the shallow groundwater at this well remains above the MCL (Table 23). Results of radiological analyses performed during CY 2001 confirm historical data showing U-234 and U-238 as the source of the elevated alpha radioactivity in the groundwater at this well. The suspected source(s) of the uranium isotopes is believed to be historical spills and leaks from nearby process buildings where large amounts of radionuclides were routinely handled (DOE 1998). Monitoring results obtained during CY 2002 also suggest that the increasing levels of alpha radioactivity indicated by historical results for the well may have peaked and started to decrease, as illustrated by the gross alpha results reported for the groundwater samples collected from the well in March 1995 (10.7 pCi/L), May 1996 (30.1 pCi/L), May 1998 (64 pCi/L), May 2000 (62 pCi/L), and May 2002 (45 pCi/L). This pattern potentially reflects a temporal "slug" in the relative flux of uranium isotopes via the groundwater flowpaths in the Nolichucky Shale that are monitored by well GW-782. Alternatively, the higher concentrations of uranium coincide with the change to low-flow sampling (Table 4) and, consequently, may be an artifact of the sampling method. Plotted separately, the conventional sampling results for gross alpha activity indicate an indeterminate trend and the low-flow sampling results for gross alpha activity indicate a generally decreasing trend (Figure A.35).

3.2.2 Aquifer Monitoring Wells

As shown in Table 24, elevated concentrations of one or more of the principal groundwater contaminants in the East Fork Regime were reported for at least one of the groundwater samples collected during CY 2002 from 16 of the surveillance monitoring wells that are completed in the Maynardville Limestone.

Table 24. East Fork Regime CY 2002: principal contaminants detected in surveillance monitoring aquifer wells

	Monitored	Inor	ganics		Radioa	Radioactivity		
Well	Interval Depth (ft bgs)	Nitrate	Uranium	VOCs	Alpha Activity	Beta Activity		
GW-153	45.0 - 60.0			•				
GW-154	4.7 - 11.2		•	•	•	•		
GW-193	5.5 - 18.4			•				
GW-219	4.3 - 11.3		•	•	•	•		
GW-223	79.0 - 90.5		•	•		•		
GW-251	35.0 - 51.0	•		•		•		
GW-253	36.2 - 50.0	•		•	•	•		
GW-381	49.3 - 60.4			•		•		
GW-382	125.0 - 173.0			•		•		
GW-605	28.2 - 39.9		•	•	•	•		
GW-606	155.0 - 171.0	•		•		•		
GW-618	26.0 - 37.0			•		•		
GW-620	61.7 - 75.0			•		•		
GW-686	4.0 - 16.0			•				
GW-689	8.0 - 20.0		•		•			
GW-698	63.0 - 75.0	•		•				
Scre	ening Level	10 mg/L	0.03 mg/L	5 μg/L	15 pCi/L	50 pCi/L		

The following sections provide separate discussions of the CY 2002 monitoring results for each major type of contaminant (inorganics, VOCs, and radioactivity).

3.2.2.1 Inorganic Contaminants

As shown below in Table 25, elevated concentrations of nitrate and uranium were detected in at least one of the groundwater samples collected during CY 2002 from nine surveillance monitoring aquifer wells in the East Fork Regime.

Table 25. East Fork Regime CY 2002: elevated nitrate and uranium concentrations in surveillance monitoring aquifer wells

		Nitrate	e (mg/L)	Uranium (mg/L)		
Well Location/Number		1st/2nd Qtr.	3rd/4th Qtr.	1st/2nd Qtr.	3rd/4th Qtr.	
		2002	2002	2002	2002	
Western Y-12 Area	GW-251	62.4	41.2	<	<	
	GW-253	852	3,100 Q			
Central Y-12 Area	GW-689 GW-698 GW-219	NS 145	48	NS < 0.359	0.058 < 0.594	

Table 25. (Continued)

			(mg/L)	Uranium (mg/L)			
Well Location/Number		1st/2nd Qtr. 3rd/4th Qtr 2002 2002		1st/2nd Qtr. 2002	3rd/4th Qtr. 2002		
Eastern Y-12 Area	GW-605	<	<	0.0983	0.114		
	GW-606	<	12				
	GW-154	<	<	0.853	0.884		
	GW-223		<	0.0343	0.0305		
MCL		10 mg/L 0.03 mg/L					
Note: "." = Not detected;	Note: "." = Not detected; "<" = Less than MCL; NS = Not sampled; Q = Qualitative result						

Historical monitoring results show that well GW-251 yields nitrate-contaminated calcium-magnesium-bicarbonate groundwater from a relatively shallow depth (<50 ft bgs) in the upper Maynardville Limestone (shallow bedrock interval) about 100 ft west (parallel with geologic strike) of the S-2 Site (Figure A.3). The nitrate in the well is probably leached directly from the S-2 Site and transported in the shallow groundwater in the Maynardville Limestone downgradient (along geologic strike) to the east and west of the site (DOE 1998). The CY 2002 monitoring results show that nitrate levels in the well remain substantially above the MCL (Table 25), with the highest nitrate concentration (62.4 mg/L) reported for the groundwater sample collected from the well in April 2002 (seasonally high flow conditions). Such seasonal concentration fluctuations are a distinctive characteristic of the nitrate data for the well (Figure A.36), with higher concentrations typically evident during seasonally high flow (e.g., April 2002) and lower concentrations evident during seasonally low flow (e.g., October 2002). In addition to the seasonal concentration fluctuations, the CY 2002 monitoring results also continue the generally decreasing long-term concentration trend indicated by historical data for the well (Figure A.36). This decreasing trend suggests a continuing decline in the overall flux of nitrate along the groundwater flowpaths in the Maynardville Limestone that are monitored by well GW-251.

Well GW-253 is completed at a depth of 50 ft bgs in the Maynardville Limestone (water table interval) near the east side of the S-2 Site about 300 ft directly east (parallel with geologic strike) of well GW-251 (Figure A.3). This well yields acidic (pH <6), nitrate-contaminated calcium-magnesium bicarbonate groundwater distinguished by very high TDS (>1,000 mg/L) in conjunction with unusually low bicarbonate alkalinity (<100 mg/L). Monitoring results obtained during CY 2002 show that the nitrate concentrations in the well remain near 1,000 mg/L (Table 25). Note that the very high nitrate concentration reported for the sample collected from the well in November 2002 (3,100 mg/L) is considered qualitative because this sample does not meet the ion-charge balance DQO required by the GWPP (the relative percent difference between the summed millequivalent concentrations of the major anions and cations must be $\pm 20\%$). Nevertheless, the nitrate levels in the groundwater at well GW-253 remain substantially higher than evident in well GW-251, which suggests greater flux of nitrate (and other contaminants) in the Maynardville Limestone to the east rather than west of the S-2 Site. Additionally, the CY 2002 monitoring results for well GW-253 continue an indeterminate long-term nitrate concentration trend, as illustrated by the nitrate results reported for the groundwater samples collected in February 1999 (952 mg/L), May 2001 (952 mg/L), and May 2002 (852 mg/L).

Well GW-689 is located near the Coal Pile Trench about 1,500 ft east-northeast (across geologic strike) of well GW-253 (Figure A.3). Completed at a depth of 20 ft bgs in the Maynardville Limestone (water table interval), this well was damaged at some time in the past. Groundwater samples were collected from the well

in November 2002 before it was permanently plugged and abandoned (in May 2003). Analytical results for this sample indicate that the well monitored very acidic (pH <3) and extremely mineralized (TDS = $10,200 \, \text{mg/L}$) groundwater distinguished by very high levels of sulfate ($6,600 \, \text{mg/L}$) and several trace metals, particularly aluminum ($262 \, \text{mg/L}$) and iron ($1,190 \, \text{mg/L}$); total uranium in this sample slightly exceeds the MCL (Table 25). These results show that the shallow groundwater in the Maynardville Limestone at well GW-689 is strongly impacted by leachate from the coal stockpile.

Well GW-698 yields highly mineralized (TDS >1,000 mg/L), nitrate-contaminated calcium-magnesiumbicarbonate groundwater from the upper Maynardville Limestone (shallow bedrock interval) near the southeast corner of Building 81-10 about 1,300 ft southeast (across geologic strike) of well GW-689 (Figure A.3). Monitoring results obtained during CY 2002 indicate that the nitrate concentrations in the well remain above the MCL (Table 25), with the highest concentration (145 mg/L) reported for the sample collected from the well in May 2002 (seasonally high flow conditions). These nitrate concentrations continue an indeterminate concentration trend indicated by previous low flow sampling results, as illustrated by the nitrate concentrations detected in the groundwater samples collected from the well in July 1998 (158 mg/L), November 2001 (221 mg/L), and November 2002 (48 mg/L). Also, the nitrate results obtained from low flow sampling are substantially higher than evident the last time the conventional sampling method was used at this well (nitrate = 25.3 mg/L in June 1996). Thus, it is not clear from the available data if the much lower nitrate concentration evident in June 1996 is an artifact of the conventional sampling method or if the nitrate levels in the well increased at some time during the subsequent two-year gap (July 1996 - July 1998) in the sampling history for this well. In either case, there are two confirmed sources of nitrate that are hydraulically upgradient of the well: the Eastern S-3 Ponds Plume and the S-2 Site. The latter is the more likely source of the nitrate in the groundwater at well GW-698 because the S-2 Site is located almost directly along geologic strike in the upper Maynardville Limestone to the west of the well, whereas the Eastern S-3 Ponds Plume occurs primarily within the Nolichucky Shale across almost the entire section of Maynardville Limestone. Also, nitrate from the Eastern S-3 Ponds Plume is usually accompanied by elevated beta radioactivity from Tc-99, which is as mobile as nitrate in the groundwater and is the "signature" contaminant of the Eastern S-3 Ponds Plume, and background levels of gross beta activity were reported for the groundwater samples collected from well GW-698 during CY 2002 (7 pCi/L in May 2002 and <MDA in November 2002).

Well GW-219 is completed at a depth of about 11 ft bgs in the Maynardville Limestone (water table interval) about 50 ft east-northeast of the Uranium Oxide Vault, which is about 2,200 ft directly east (hydraulically downgradient along geologic strike) of well GW-698 (Figure A.3). Historical data show that well GW-219 yields calcium-magnesium-bicarbonate groundwater containing elevated total and dissolved uranium concentrations; the source of the uranium in the well has not been confirmed, but is probably the Uranium Oxide Vault (DOE 1998). As shown on Table 25, the groundwater monitoring results obtained during CY 2002 show that uranium concentrations in the well remain at least an order-of-magnitude above the MCL. These results also continue the indeterminate concentration trend evident since the late 1990s, as illustrated by the similar levels of uranium reported for the groundwater samples collected from the well in December 1999 (0.599 mg/L), October 2000 (0.449 mg/L), November 2001 (0.6 mg/L), and November 2002 (0.594 mg/L).

Historical data show that well GW-605, which is completed at a depth of 40 ft bgs in the upper Maynardville Limestone (shallow bedrock interval) approximately 3,100 ft east (hydraulically downgradient along geologic strike) of well GW-219 (Figure A.3), yields calcium-magnesium-bicarbonate groundwater that also is distinguished by elevated uranium concentrations. The specific source of the uranium in the shallow groundwater at this well has not been identified, but the well may penetrate fill material containing low-level

radioactive materials derived from historical uranium enrichment activities performed in Buildings 9201-1, 9201-2, and 9201-3 (DOE 1998). The CY 2002 monitoring results show that the total uranium levels in the well remain above the MCL (Table 25) and, along with the historical uranium results, continue an indeterminate long-term concentration trend, as illustrated by the uranium concentrations detected in the groundwater samples collected in August 1991 (0.12 mg/L), September 1995 (0.16 mg/L), July 2000 (0.0897 mg/L), and July 2002 (0.114 mg/L).

Clustered with well GW-605, well GW-606 yields chloride- (>30 mg/L) and sulfate-enriched (>80 mg/L) calcium-magnesium-bicarbonate groundwater from more than 150 ft bgs in the upper Maynardville Limestone (intermediate bedrock interval). The nitrate concentration reported for the groundwater sample collected from the well in July 2002 (12 mg/L) exceeds the MCL and is about double the historical high nitrate level for the well (6.3 mg/L in July 2000). Nitrate levels in the groundwater at this well have increased from less than 1 mg/L during the early and mid-1990s (e.g., 0.78 mg/L in October 1991 and 0.72 mg/L in September 1994) to about 5 mg/L through January 2002; the significance of this increasing trend is evaluated in Section 5.2.

Wells GW-154 and GW-223 are clustered in the Maynardville Limestone (water table interval and shallow bedrock interval, respectively) near the western (hydraulically upgradient) side of NHP about 1,350 ft east-northeast of wells GW-605 and GW-606 (Figure A.3). Historical data show that well GW-154, which is the shallower well (11 ft bgs), yields moderately mineralized (TDS >500 mg/L), sulfate-enriched (>100 mg/L) calcium-magnesium-bicarbonate groundwater distinguished by very high (>1 mg/L) total uranium concentrations. Monitoring results obtained during CY 2002 show that uranium levels in the groundwater at this well remain at least an order-of-magnitude above the MCL (Table 25), with the concentration reported for the sample collected in August 2002 (0.884 mg/L) being the second-highest uranium level detected in the well since the mid-1980s (see Section 5.2). Well GW-223, which is completed at a depth of 90 ft bgs, also yields sulfate-enriched (>35 mg/L) calcium-magnesium-bicarbonate groundwater. However, uranium levels in the deeper groundwater at this well are substantially lower than evident in the shallower groundwater at well GW-154; as shown on Table 25, total uranium concentrations detected in the groundwater samples collected from well GW-223 during CY 2002 are just above the MCL. Nevertheless, these results continue the increasing concentration trend indicated by historical uranium data for the well (see Section 5.2).

3.2.2.2 Volatile Organic Compounds

Groundwater samples collected during CY 2002 from 13 of the surveillance monitoring aquifer wells in the East Fork Regime contained one or more dissolved VOCs at individual or summed concentrations of 5 μ g/L or more. Summed concentrations of the VOCs detected in these wells range from less than 50 μ g/L (GW-193 and GW-620) to more than 1,000 μ g/L (GW-253). As shown in Table 26, the maximum concentrations of PCE, TCE, c12DCE, VC, CTET, MC, and benzene reported for the groundwater samples from at least one of these wells exceed corresponding MCLs.

Table 26. East Fork Regime CY 2002: maximum VOC concentrations in surveillance monitoring aquifer wells

***			Maximum	Concentrati	on (µg/L)		
Well	PCE	TCE	c12DCE	VC	CTET	MC	Benzene
Western Y-12 Area GW-620	17	7	<				
GW-251	230	130	<		6		
GW-253 GW-618	680 7	610 16	260 <	63 3	35	•	
Central Y-12 Area GW-686 GW-698 GW-193	150	340	< <	11	11		25
Eastern Y-12 Area GW-605 GW-606 GW-381 GW-382 GW-223 GW-153	76 7 5 J 9 J 45 <	82 15	140 < < <	2	53 180 380 510	120 43	
MCL (µg/L)	5	5	70	2	5	5	5
Note : ". " = Not detec	ted; "<" = Le	ss than the M	CL; J = estima	ated concentr	ation		

Well GW-620 is completed at a depth of 75 ft bgs in the Maynardville Limestone (shallow bedrock interval) about 100 ft north-northeast of the Fire Training Facility (Figure A.3) and is the westernmost aquifer well in the East Fork Regime that was sampled during CY 2002. This well yields chemically distinctive groundwater distinguished by strongly basic pH (e.g., field measurement of 12.26 in April 2002), atypically low bicarbonate alkalinity (e.g., 32 mg/L in April 2002), and unusually high potassium concentrations (e.g., 14.1 mg/L in April 2002). Groundwater in the well also contains a mixture of dissolved chloroethenes, chloroethanes, and petroleum hydrocarbons that are believed to originate from the historical operations of former burn areas in the western part of the Fire Training Facility (DOE 1998). Monitoring results obtained during CY 2002 show the highest concentrations for PCE (17 μ g/L) and c12DCE (17 μ g/L), lower levels for TCE (7 μ g/L), and traces (<5 μ g/L) of toluene and DMB; note that the PCE and TCE concentrations exceed respective MCLs (Table 26). These CY 2002 groundwater monitoring results continue the decreasing long-term concentration trend indicated by historical VOC data for the well (Figure A.37).

Well GW-251 monitors the plume of dissolved chloroethenes (primarily PCE and TCE) and chloromethanes (CTET and chloroform) in the Maynardville Limestone (shallow bedrock interval) hydraulically downgradient to the west (parallel with geologic strike) of the S-2 Site (DOE 1998). Groundwater monitoring results obtained during CY 2002 show that: (1) the summed maximum concentrations of chloroethenes (371 μ g/L) remain substantially higher than the summed maximum concentrations of chloromethanes (17 μ g/L); (2) the maximum concentrations of PCE and TCE exceed respective MCLs (Table 26); and (3) the concentrations of PCE (230 μ g/L) and TCE (130 μ g/L) evident in April 2002 (seasonally high flow) are substantially higher than the concentrations of PCE (81 μ g/L) and TCE (38 μ g/L) evident in October 2002 (seasonally low flow). Seasonally variable concentrations of VOCs in the groundwater at this well reflect the flushing of VOCs (and other contaminants) from the shallow karst network in the Maynardville Limestone (DOE 1998). The CY 2002 monitoring results also continue the indeterminate long-term VOC concentration trend indicated by historical data for well GW-251, as illustrated by the summed concentrations of VOCs

detected in the groundwater samples collected in April 1992 (332 μ g/L), May 1994 (366 μ g/L), May 1996 (284 μ g/L), May 1998 (654 μ g/L), May 2000 (476 μ g/L), and April 2002 (388 μ g/L).

Well GW-253 monitors the plume of dissolved VOCs in the Maynardville Limestone (shallow bedrock interval) hydraulically downgradient to the east (parallel with geologic strike) of the S-2 Site, and the groundwater monitoring results obtained during CY 2002 show that maximum concentrations of PCE (680 μ g/L), TCE (610 μ g/L), c12DCE (260 μ g/L), VC (63 μ g/L), and CTET (35 μ g/L) in the well remain substantially above respective MCLs (Table 26). As in previous years, the summed maximum concentration of the VOCs detected in the respective groundwater samples collected from the well during CY 2002 (1,687 μ g/L) is substantially higher than evident for well GW-251 (388 μ g/L). This suggests greater eastward rather than westward flux of dissolved VOCs via strike-parallel groundwater flowpaths in the Maynardville Limestone downgradient of the S-2 Site. Monitoring results obtained during CY 2002 also continue the increasing concentration trend indicated by historical data for c12DCE and VC in well GW-253 (see Section 5.2).

Well GW-618 is located about 700 ft east-northeast of well GW-253 (Figure A.3) and is completed at a depth of 37 ft bgs in the lower Maynardville Limestone (water table interval). This well yields calcium-magnesium-bicarbonate groundwater containing a mixture of dissolved chloroethenes that originate from one or more upgradient sources in the western Y-12 area (DOE 1998). Relatively low summed concentrations of PCE, TCE, c12DCE, and VC were detected in the groundwater samples collected from the well in May (32 $\mu g/L$) and November 2002 (57 $\mu g/L$), but the maximum concentrations of PCE , TCE, and VC exceed respective MCLs (Table 26). These VOC results are consistent with historical monitoring data for the well and continue an indeterminate long-term concentration trend, as illustrated by the total 12DCE results for the groundwater samples collected from in November 1992 (36 $\mu g/L$), October 1996 (52 $\mu g/L$), November 2000 (29 $\mu g/L$), and November 2002 (31.5 $\mu g/L$).

Well GW-686 is completed at a depth of 17 ft bgs in the Maynardville Limestone southeast of the Coal Pile Trench and about 1,200 ft east-southeast of well GW-618 (Figure A.3). Although the well was installed in October 1990, data are available only for groundwater samples collected from the well in March 1998 and November 2002. Analytical results for these samples indicate that the well yields sulfate-enriched (>150 mg/L) calcium-magnesium-bicarbonate groundwater distinguished by unusually high concentrations (>10 mg/L) of aluminum and iron. These results also show low levels of PCE degradation products in the groundwater at this well; both c12DCE and VC were detected in the groundwater samples collected from the well in March 1998 (6 μ g/L and 1 μ g/L, respectively) and November 2002 (36 μ g/L and 11 μ g/L, respectively). Note that the latter VC concentration exceeds the MCL (2 μ g/L). Although leachate from coal stockpile undoubtedly has contaminated the shallow groundwater in the Maynardville Limestone in the vicinity of this well, it seems an unlikely source of VOCs in well GW-686. Moreover, there are multiple potential sources of VOCs hydraulically upgradient of the well (e.g., Y-12 Salvage Yard).

The nitrate-contaminated groundwater in the upper Maynardville Limestone (shallow bedrock interval) at well GW-698 contains a mixture of dissolved chlorinated solvents dominated by PCE and TCE. The specific source of the VOCs in the well is not known, but may be the S-2 Site or the WCPA (DOE 1998). Groundwater monitoring data obtained during CY 2002 show high concentrations of TCE (>300 $\mu g/L$) and PCE (>100 $\mu g/L$) in the well along with much lower levels (<50 $\mu g/L$) of c12DCE, CTET, and chloroform; maximum concentrations of TCE, PCE, and CTET exceed respective MCLs (Table 26). The results for these VOCs continue the divergent concentration trends indicated by previous low flow sampling results, as illustrated by the decreasing concentrations of PCE and TCE (Figure A.38) and increasing concentrations of c12DCE (see Section 5.2). However, these VOC concentrations are substantially higher than evident the last time the conventional sampling method was used at this well (summed VOCs = 20 $\mu g/L$ in June 1996).

Well GW-193 is completed at a depth of about 18 ft bgs in the lower Maynardville Limestone (water-table interval) near the eastern end of Building 9201-1, approximately 2,500 east (hydraulically downgradient along geologic strike) of well GW-698 (Figure A.3). This well yields calcium-magnesium-bicarbonate groundwater containing a residual plume of dissolved petroleum hydrocarbons that originated from historical operation of a gasoline UST (Tank 2331-U) that was excavated and removed in December 1988 (DOE 1998). Benzene was the only VOC detected in the groundwater sample collected from the well in January 2002 (25 µg/L); VOCs were not detected in the groundwater sample collected from the well in July 2002. Along with the historical data, the CY 2002 monitoring results for benzene in well GW-193 continue the widely fluctuating but generally decreasing long-term concentration trend (Figure A.39).

Shallow groundwater in the upper Maynardville Limestone at well GW-605, which is about 2,500 ft southeast (across geologic strike) of well GW-193 (Figure A.3), contains a mixture of dissolved chloroethenes (PCE, TCE, and c12DCE) and chloromethanes (CTET and chloroform). Monitoring results obtained during CY 2002 show that the concentrations of PCE, TCE, c12DCE, and CTET in the well remain above respective MCLs (Table 26). Also, the groundwater sample collected from the well in January 2002 (seasonal high flow conditions) has a substantially higher summed VOC concentration (363 µg/L) compared to the summed VOC concentration (147 µg/L) for sample collected in July 2002 (seasonally low flow conditions). As noted in Table 4 and illustrated by the data summarized below in Table 27, the CTET concentrations reported for groundwater samples obtained with the low-flow sampling method are substantially lower than the concentrations evident in the samples obtained with the conventional sampling method; PCE, TCE, and c12DCE levels are higher in samples obtained with the low flow method; and there are only minor differences between the concentrations of chloroform in the samples obtained with either method.

Table 27. Selected VOC data for well GW-605

	Concentration (µg/L)									
VOC	Conventional Sampling Low-Flow Sampling					Conventional Sampling Low-Flow Sampling			g	
	Feb. 1996	June 1996	Mar. 1997	Aug. 1997	Mar. 1998	July 1998	Jan. 2000	July 2000	Jan. 2002	July 2002
PCE	21	14	3 J	7		35	15	54	76	33
TCE	8	5	1 J	2 J		43	16	57	82	33
c12DCE	21	13	3 J	5	•	79	27	100	140	50
CTET	190	250	100	170	4 J	42	11	62	53	19
Chloroform	26	23	FP	16		11	7	10	11	12
Note: "." = No	t detected	; J = Estin	nated con	centration	; FP = Fals	se positive	;			

Assuming that the groundwater in the well contains a heterogeneous mixture of dissolved VOCs, it is not clear why the concentrations of individual compounds exhibit different responses to the groundwater sampling method. Perhaps the higher pumping rate during conventional sampling induces upward flow of CTET-contaminated groundwater from the deeper in the Maynardville Limestone, which increases the CTET concentrations relative to other VOCs in the samples from the well, whereas low-flow sampling induces lateral inflow of PCE-, TCE-, and c12DCE-contaminated groundwater from the shallow flow system, resulting in samples with higher concentrations of these compounds relative to CTET. Separate plots of the conventional sampling and low flow sampling results for CTET indicate widely variable and indeterminate concentrations trends (Figure A.40). The monitoring results for other VOCs in the well likewise reflect generally indeterminate long-term concentration trends, as illustrated by the (conventional sampling and low flow sampling) data for PCE and chloroform (Figure A.41). Also, the monitoring results for CTET and other

VOCs do not appear to exhibit any response to the extraction of groundwater from plume capture well GW-845, which is about 2,400 ft directly east (hydraulically upgradient along geologic strike) of well GW-605 (Figure A.3) and has been pumped continuously since October 2000 to capture the CTET-dominated VOC plume in the Maynardville Limestone before it exits the eastern Y-12 area (see Section 2.4.1.1).

Clustered with GW-605, well GW-606 yields groundwater from deeper in the Maynardville Limestone (171 ft bgs) that contains a mixture of CTET and chloroform along with traces of PCE. Monitoring results obtained during CY 2002 show that CTET and chloroform concentrations remain above 100 μ g/L, with the groundwater sample collected in January 2002 having the highest concentration of chloroform (230 μ g/L) and sample collected in July 2002 having the highest concentration of CTET (180 μ g/L); similar levels of PCE (5 μ g/L and 7 μ g/L, respectively) were detected in each sample. Along with historical data for the well, the CY 2002 monitoring results continue the somewhat divergent concentration trends for CTET and chloroform (Figure A.42). Conventional sampling results show that CTET concentrations decreased substantially between October 1991 (2,600 μ g/L) and July 1997 (67 μ g/L), with subsequent low-flow sampling results showing an indeterminate trend ranging between 50 μ g/L (January 2000) and 180 μ g/L (July 2002). As shown on Figure A.42, chloroform results indicate a similarly decreasing concentration trend between October 1991 (640 μ g/L) and July 1997 (66 μ g/L), followed by a steadily increasing trend through July 2000 (430 μ g/L) and a subsequently decreasing trend though July 2002 (140 μ g/L). The latter decrease in the chloroform concentrations may be a response to the operation of plume capture well GW-845.

Wells GW-381 and GW-382 are clustered in the upper Maynardville Limestone about 1,000 ft directly east (hydraulically downgradient along geologic strike) of wells GW-605 and GW-606 (Figure A.3). Historical data show that well GW-381, which is completed at a depth of 60 ft bgs (shallow bedrock interval), yields chloride-enriched (>60 mg/L) calcium-magnesium-bicarbonate groundwater containing very high concentrations of CTET (>1,000 μ g/L) and chloroform (>500 μ g/L). The source of the CTET may be DNAPL in the subsurface south of Building 9720-6 (BJC 1998). Monitoring results obtained during CY 2002 show that CTET and chloroform concentrations in the groundwater at this well remain above 100 μ g/L, with large seasonal concentration fluctuations suggested by the substantial difference between the summed VOC concentrations in June 2002 (1,131 μ g/L) and October 2002 (192 μ g/L). Along with the historical data for CTET and chloroform, the CY 2002 monitoring results continue the decreasing long-term concentrations trends evident for each compound (Figure A.43). Note also that the concentrations of both VOCs seem to exhibit larger temporal fluctuations following the full-time operation of plume capture well GW-845, which is about 1,500 ft east (hydraulically upgradient along geologic strike) of wells GW-381 and GW-382 (Figure A.3).

As with the shallower groundwater in well GW-381, the chloride-enriched (>50 mg/L) calcium-magnesium-bicarbonate groundwater deeper in the Maynardville Limestone at well GW-382, which is completed at a depth of 173 ft bgs (intermediate bedrock interval), contains a mixture of dissolved VOCs dominated by CTET and chloroform. The CY 2002 monitoring results show VOC concentrations in the well that are similar to those in the shallower groundwater at well GW-381, with CTET and chloroform concentrations above 100 μ g/L and seasonal concentration fluctuations reflected by the summed VOC levels evident in February 2002 (902 μ g/L) and August 2002 (682 μ g/L). Also, the PCE concentrations reported for these groundwater samples (8 μ g/L and 9 μ g/L, respectively) exceed the MCL. Along with the historic data for the well, the CY 2002 groundwater monitoring results continue: (1) the steadily decreasing long-term concentration trend indicated by the historical results for CTET; (2) the indeterminate PCE concentration trend indicated by the low-flow sampling results obtained since May 2000, which reflect substantially lower PCE levels than evident in the well before a four-year gap in the sampling history; and (3) the widely variable but generally higher concentrations of chloroform compared to historical levels in the well (Figure A.44). Additionally, the concentrations of VOCs in the groundwater at this well do not appear to exhibit any response to the operation of plume capture well GW-845.

As noted in Section 3.2.2.1, well GW-223 is clustered with well GW-154 on the western side of NHP (Figure A.3) and is completed at a depth of 90 ft bgs in the lower Maynardville Limestone about 500 ft northeast (across geologic strike) of wells GW-381 and GW-382 (Figure A.3). Historical monitoring data show that the sulfate-enriched calcium-magnesium-bicarbonate groundwater in well GW-223 contains a mixture of dissolved VOCs, dominated by PCE and its degradation products, that are believed to originate from the former Oil Skimmer Basin, which was located at the inlet to NHP and was closed along with the pond in November 1989 (DOE 1998). Groundwater monitoring results obtained during CY 2002 show the highest concentrations for PCE (45 μ g/L) and c12DCE (52 μ g/L), with lower levels of TCE (15 μ g/L) and VC (2 μ g/L); note that the PCE, TCE, and VC concentrations meet or exceed respective MCLs (Table 26). Additionally, the CY 2002 monitoring results continue the divergent long-term concentration trends indicated by historical VOC data for well GW-223, with a generally increasing trend for 12DCE (see Section 5.2) in conjunction with decreasing trends for the other VOCs in the well, as illustrated by the PCE concentrations in the well (Figure A.45).

Well GW-153 is located on the south side of NHP about 600 ft southeast (across with geologic strike) of well GW-223 and about 700 ft directly west (hydraulically upgradient along geologic strike) of plume capture well GW-845 (Figure A.3). Completed at a total depth of 60 ft in the upper Maynardville Limestone (shallow bedrock interval), this well yields calcium-magnesium-bicarbonate groundwater containing a mixture of dissolved VOCs dominated by CTET. The CY 2002 groundwater monitoring results show that the CTET concentrations in the well exceed the MCL and remain above $100\,\mu\text{g/L}$ (Table 26). Low levels of chloroform (7 $\mu\text{g/L}$) and PCE (<5 $\mu\text{g/L}$) also were detected in the groundwater samples collected from the well during CY 2002. Also, the CTET and chloroform concentrations evident during CY 2002 reflect the overall decrease from higher concentrations evident before the full-time operation of plume capture well GW-845 (Figure A.46).

3.2.2.3 Radioactivity

As shown in Table 28, elevated gross alpha activity (>15 pCi/L) or gross beta activity (>50 pCi/L) was reported for the groundwater samples collected during CY 2002 from surveillance monitoring aquifer wells in the East Fork Regime that are located in the western Y-12 area (GW-253), central Y-12 area (GW-219 and GW-689), and eastern Y-12 area (GW-154 and GW-605).

Table 28. East Fork Regime CY 2002: elevated gross alpha activity and gross beta activity in surveillance monitoring aquifer wells

**/ 11	Date	Gı	oss Alpha (pCi/L)	Gross Beta (pCi/L)			
Well	Sampled	MDA	Activity ± CE	MDA	Activity ± CE		
Western Y-12 Area GW-253 GW-253	05/07/02 11/07/02	5.53 11.43	45.1 ± 9.67 29.98 ± 12.51	10.73 8.35	< <		
Central Y-12 Area GW-689 GW-219 GW-219	11/14/02 05/06/02 11/07/02	53 4 7.6	100 ± 56 120 ± 13 170 ± 15	140 8 7.1	<mda 77 ± 9.5 91 ± 8.8</mda 		

Table 28. (Continued)

Well	Date	Gr	oss Alpha (pCi/	L)	Gross Beta (pCi/L)			
Well	Sampled	MDA	Activity ± CE		MDA	Activity ± CE		CE CE
Eastern Y-12 Area								
GW-605	01/08/02	2.83	$48.42 \pm$	5.12	2.29		<	
GW-605	07/08/02	2.21	51.84 ±	4.16	1.88		<	
GW-154	01/30/02	3.76	$755.5 \pm$	23.6	2.37	103.7	土	4.4
GW-154	08/05/02	4.98	1,270.6 ±	30.9	3.85	275.9	±	7.6
Screening Lev	rel		15 pCi/L		50 pCi/L			
L								

Note: "<" = Exceeds the MDA, but less than the screening level

Elevated levels of alpha radioactivity in the groundwater at well GW-253 are believed to be from uranium isotopes emplaced in the aquifer (Maynardville Limestone) during operation of the S-2 Site (DOE 1998). Gross alpha activity reported for the groundwater samples collected from the well during CY 2002 exceed the MCL (Table 28) and are consistent with historical data, which indicate a generally decreasing or indeterminate long-term trend characterized by wide temporal fluctuations. Also, the highest gross alpha activities are typically reported for groundwater samples collected from the well during seasonally low flow conditions, as illustrated by the series of gross alpha results for the samples collected in November 2000 (74 pCi/L), May 2001 (25 pCi/L), October 2001 (102 pCi/L), May 2002 (45 pCi/L), and November 2002 (29.98 pCi/L). It is possible, however, that many of the results which show elevated gross alpha (or gross beta) activity are inaccurate because of analytical interferences from the very high levels of dissolved solids in the (unfiltered) groundwater samples from well GW-253 (e.g., TDS = 4,990 mg/L in November 2002).

Although there are limited sampling results for well GW-689, monitoring data obtained during CY 2002 show that the highly contaminated groundwater in the Maynardville Limestone at this well contains total uranium concentrations above the MCL (see Section 3.2.2.1), which may indicate that uranium isotopes are the source of the elevated alpha radioactivity in the well. It is also possible, however, that the elevated gross alpha activity reported for the sample collected from the well in November 2002 is an artifact of analytical interferences related to the very high dissolved solids in this sample (TDS = 10,200 mg/L).

As noted in Section 3.2.2.1, well GW-219 yields uranium-contaminated groundwater from the Maynardville Limestone (water table interval) near the Uranium Oxide Vault (Figure A.3). Monitoring results obtained during CY 2002 show that gross alpha and gross beta activity in the well remain above respective screening levels (Table 28), with the highest value for each parameter reported for the sample collected from the well in November 2002 (seasonally low flow conditions). Results of radiological analyses of the groundwater sample collected from the well in May 2001 show that the elevated alpha radioactivity is from U-234 (29 pCi/L) and U-238 (190 pCi/L); uranium decay products in the groundwater (e.g., Th-234) are the likely source of the beta radioactivity in the well. Additionally, the CY 2002 monitoring results for the well continue the relatively indeterminate long-term alpha radioactivity trend indicated by historical data, as illustrated by the gross alpha activity reported for the groundwater samples collected in December 1999 (180 pCi/L), June 2000 (100 pCi/L), May 2001 (200 pCi/L), and November 2002 (170 pCi/L).

The uranium-contaminated groundwater in the Maynardville Limestone at well GW-605 contains elevated alpha radioactivity from uranium isotopes that originate at an unidentified but presumably nearby source area (DOE 1998). The groundwater monitoring results obtained during CY 2002 show that alpha radioactivity in this well remains near 50 pCi/L and are consistent with the sharp drop in gross alpha activity evident since

July 1998 (29 pCi/L). Whatever the cause, the decrease from the higher historical levels of alpha radioactivity (e.g., 104 pCi/L in September 1994, 132 pCi/L in September 1996, and 130 pCi/L in March 1998) potentially reflects a corresponding decrease in the relative flux of uranium isotopes via the groundwater flowpaths in the Maynardville Limestone that are monitored by well GW-605.

Of all the surveillance monitoring aquifer wells in the East Fork Regime that were sampled during CY 2002, the groundwater samples from well GW-154 had the highest levels of gross alpha and gross beta activity (Table 28). Radiological analyses of the groundwater samples collected from the well during CY 2002 show that the alpha radioactivity is from uranium isotopes, with similar activities evident in January (U-234 = 393 pCi/L and U-238 = 251 pCi/L) and August 2002 (U-234 = 295 pCi/L and U-238 = 248 pCi/L). Also, based on these results and assuming equilibrium with U-238, the beta radioactivity in the well is primarily from Th-234. The source of the uranium isotopes in the groundwater at this well is believed to be the Oil Skimmer Basin formerly located at the inlet of NHP (DOE 1998). Along with historical data, the CY 2002 monitoring results continue a generally increasing trend for gross alpha activity (see Section 5.2) whereas the gross beta activity in the well sharply increased during closure of the site in 1989, rapidly decreased through the early 1990s, with more moderated decreases evident since the mid 1990s (Figure A.47).

3.2.3 Union Valley

Monitoring results obtained during CY 2002 for six wells (GW-169, GW-170, GW-171, GW-172, GW-230, and GW-232) and two springs (SCR 7.1SP and SCR7.8SP) located in Union Valley east of Y-12 (Figure A.3) were evaluated to meet the surveillance monitoring requirements of DOE Order 5400.1. Groundwater samples were collected from each of these wells and springs semiannually during CY 2002. As shown below in Table 29, VOCs that are components of the groundwater contaminant plume(s) in the eastern Y-12 area were detected in at least one of the groundwater samples collected from wells GW-169, GW-170, and GW-230.

Table 29. Union Valley CY 2002: principal groundwater contaminants detected at surveillance monitoring sampling locations

Sampling	Monitoring Interval Depth	Contaminant Type				
Location	(ft bgs)	Inorganics	VOCs	Radioactivity		
GW-169	28.7 - 34.7		•			
GW-170	104.0 - 156.9		•			
GW-171	28.5 - 31.2					
GW-172	105.0 - 133.8					
GW-230	341.0 - 406.4		•			
GW-232	401.0 - 411.7					
SCR7.1SP						
SCR7.8SP						

Well GW-169 is part of a three-well cluster (with GW-170 and GW-232) located near the base of Chestnut Ridge about 1,500 ft east of the ORR boundary along Scarboro Road (Figure A.3). Completed at a depth of 35 ft bgs in the upper Maynardville Limestone (water table interval), this well was sampled during each quarter of CY 2002. Historical monitoring data show that this well yields groundwater with low levels of PCE and TCE, although the latter compound has not been detected in any of the groundwater samples collected from the well since February 1999 (1 μ g/L). In contrast, low levels of PCE (<5 μ g/L) have been

detected in all but one of the 31 groundwater samples collected from the well since March 1991, including all four of the samples collected from the well during CY 2002 (1 - $2 \mu g/L$).

Groundwater samples also were collected from well GW-170 during each quarter of CY 2002, and each of these samples had trace levels (1 - 5 μ g/L) of PCE, TCE, and CTET. Low levels of chloroform (6 - 8 μ g/L) were detected in three of the samples, benzene was detected in the samples collected in February (3 μ g/L) and May 2002 (4 μ g/L), and a trace of toluene (0.4 μ g/L) was detected in the sample collected in November 2002. Each of these compounds was detected in at least one of the groundwater samples previously collected from the well. All of the 35 groundwater samples that have been collected from the well since March 1991 had low levels of TCE (<5 μ g/L) and/or PCE (<10 μ g/L) and the respective results for each compound show an indeterminate long-term concentration trend, as illustrated by the TCE concentrations reported for the samples collected in February 1992 (2 μ g/L), February 1994 (2 μ g/L), March 1996 (3 μ g/L), February 1999 (3 μ g/L), January 2000 (2 μ g/L), and February 2002 (1 μ g/L). The CY 2002 monitoring results continue the indeterminate CTET concentration trend evident since January 2000, with the previous monitoring results showing much higher CTET concentrations (e.g., 200 μ g/L in November 1994) that exhibit substantial short-term fluctuations (Figure A.48). Likewise, the CY 2002 results for chloroform continue an indeterminate long-term trend that follows the higher and more variable concentrations evident in the well through December 1995 (Figure A.48).

Well GW-230 is the deepest well (341 - 406.4 ft bgs) in a three-well cluster (with GW-171 and GW-172) located about 3,000 ft east of wells GW-169 and GW-170 (Figure A.3) and about 6,200 ft east of the nearest confirmed source of VOCs at Y-12 (Building 9720-6). This well yields chloride-enriched (>100 mg/L) calcium-magnesium-bicarbonate groundwater containing a mixture of dissolved VOCs, primarily c12DCE and VC. Both of these compounds were detected in the groundwater samples collected from the well during CY 2002, with VC concentration evident in February 2002 (4 μ g/L) exceeding the MCL (2 μ g/L). Along with the historical VOC data for this well, the CY 2002 monitoring results continue a relatively indeterminate concentration trend, as illustrated by the 12DCE concentrations reported for the groundwater samples collected from the well in November 1994 (17 μ g/L), June 1996 (13 μ g/L), August 2000 (13 μ g/L), and August 2002 (10 μ g/L).

3.3 CHESTNUT RIDGE REGIME

Monitoring results obtained during CY 2002 show that most of the wells in the Chestnut Ridge Regime which meet the surveillance monitoring requirements of DOE Order 5400.1 continue to yield uncontaminated, calcium-magnesium-bicarbonate groundwater. As shown in Table 30, however, one or more groundwater contaminants were detected in at least one of the groundwater samples collected during CY 2002 from 11 monitoring wells in the Chestnut Ridge Regime.

Table 30. Chestnut Ridge Regime CY 2002: principal groundwater contaminants detected in surveillance monitoring wells

Well Number a	nd Monitored Interval Depth	Contaminant Type			
	(ft bgs)	Inorganics	VOCs	Radioactivity	
GW-144	148.0 - 195.0		•		
GW-177	132.0 - 145.0		•		
GW-205	154.0 - 164.0	•		•	

Table 30. (Continued)

Well Number a	Well Number and Monitored Interval Depth			Contaminant Type			
	(ft bgs)		Inorganics	VOCs	Radioactivity		
GW-302	121.5	- 134.8	•				
GW-305	165.3	- 179.6	•	•			
GW-339	101.0	- 114.0	•				
GW-522	183.0	- 195.3		•			
GW-544	91.0	- 109.3		•			
GW-757	134.0	- 166.7	•				
GW-796	122.9	- 136.5		•			
GW-798	122.0	- 135.4		•			

The following evaluation of the CY 2002 monitoring results for these wells is organized into separate discussions for each major type of groundwater contaminant.

3.3.1 Inorganic Contaminants

Monitoring results obtained during CY 2002 show that well GW-205 at the United Nuclear Corporation Site (UNCS) and GW-757 at Industrial Landfill II (Figure A.5) continue to yield groundwater samples with geochemical characteristics that differ substantially from other wells in the Chestnut Ridge Regime and probably reflect localized contamination from the cement grout circulated into the surrounding bedrock during installation of the wells. As shown by the data summarized in Table 31, the unusual geochemistry of the groundwater in these wells includes unusually high pH, elevated concentrations of potassium, and atypically low concentrations of calcium and magnesium compared to other wells in the Chestnut Ridge Regime that yield uncontaminated groundwater, as illustrated by data for well GW-221.

Table 31. Geochemical characteristics indicative of potential grout contamination in wells GW-205 and GW-757

Suspected Grout Contamination				
GW-757	GW-757			
' I ' I	y July 2002			
139 43.	43.6			
. 70.	70.7			
6 3.2 2.9	2.9			
3.7 3	3.3			
17.7 17.	17.1			
41 41	41.3			
3 10.11 9.4	9.47			
-	4 41			

Because grout contamination is a chronic problem with respect to obtaining representative groundwater samples from wells GW-205 and GW-757, they should be extensively purged (i.e., redeveloped) prior to low-flow sampling, or the conventional sampling method should be used in order to ensure collection of minimally grout-contaminated groundwater samples from either well. Otherwise, neither well should be used to monitor groundwater quality.

As in previous years, the concentrations of (total) nickel detected in the groundwater samples collected from wells GW-302, GW-305, and GW-339 during CY 2002 exceed the State MCL (0.1 mg/L), with the highest concentrations evident in January 2002 for well GW-302 (0.32 mg/L), in May 2002 for well GW-305 (0.76 mg/L), and in July 2002 for well GW-339 (0.2 mg/L). Because these wells are not located near any known or suspected sources of nickel, corrosion of the stainless steel well casing and screen in each well is the suspected source of the elevated chromium and/or nickel concentrations in the groundwater samples. Geochemical conditions that are corrosive to stainless steel (e.g., dissolved oxygen >1 mg/L; Driscoll 1986) are evident in each of these wells. Results of microbiologic sampling performed by the Y-12 GWPP indicated microbial activity in the groundwater at each well (BWXT 2001c) and the microorganisms may facilitate corrosion of the stainless steel well casing and screen in these wells (Sarouhan et al. 1998). Although direct visual evidence (e.g., nodular formations) of microbiologically-induced corrosion was not observed during a borehole camera survey of well GW-305 (LMES 1999), two unidentified cylindrical objects were observed at the bottom of the well and if either object is metallic (the composition of the objects could not be determined from the camera survey; LMES 1999), then galvanic corrosion also may be occurring in this well.

3.3.2 Volatile Organic Compounds

Excluding results for several common laboratory reagents (e.g., acetone) that were detected in many of the groundwater (and surface water) samples collected by the WRRP during CY 2002, one or more VOCs were detected in at least one of the groundwater samples collected during CY 2002 from nine of the surveillance monitoring wells in the Chestnut Ridge Regime: GW-144 at Kerr Hollow Quarry; GW-177 at the CRSP; GW-539 at Industrial Landfill II; GW-305 and GW-522 at Industrial Landfill IV; GW-796 at Industrial Landfill V; GW-544 at Construction/Demolition Landfill VI; and GW-564 and GW-798 at Construction/Demolition Landfill VII (Figure A.5). However, the trace levels (<1 μ g/L) of the VOCs detected in the groundwater samples collected from well GW-522 in July 2002 (PCE = 0.43 μ g/L), from well GW-539 in July 2002 (11DCE = 0.37 μ g/L), and from well GW-564 in January 2002 (chloroform = 0.3 μ g/L) are suspected analytical artifacts because none of these wells have a prior history of VOC contamination. As shown below in Table 32, the summed maximum concentrations of the VOCs detected in the groundwater samples from the remaining six wells range from less than 1 μ g/L in wells GW-144 and GW-796 to just under 50 μ g/L in well GW-177 (Table 32).

Table 32. Chestnut Ridge Regime CY 2002: maximum concentrations of VOCs in surveillance monitoring wells

		Maximum Concentration (μg/L)									
Well	111TCA	11DCA	11DCE	PCE	TCE	c12DCE	TCFM	Chloro- form	Total		
GW-144 GW-177	16	25	. 8	0.4 J					0.4 49		
GW-305	22	15	4.3						41.3		

Table 32. (Continued)

	Maximum Concentration (μg/L)													
Well	111TCA	11DCA	11DCE	PCE	ТСЕ	c12DCE	TCFM	Chloro- form	Total					
GW-544 GW-796 GW-798	0.8 J 4 J	3 J	2.2	7.1	0.78 J	7	11	2.4 J	2.4 0.8 35					
MCL (µg/L)	200	NA	7	5	5	70	NA	NA	NA					
Note : "." = No	ot detected;	J = Estima	ted concent	Note: "." = Not detected; J = Estimated concentration; NA = Not applicable										

Well GW-144 is located on the south side (hydraulically downgradient) of Kerr Hollow Quarry (Figure A.5) and is completed with a nominal 50-ft open-hole interval in the upper Knox Group (148 - 195 ft bgs). This well has an extensive history of quarterly and semiannual RCRA groundwater monitoring that includes several years during which four replicate samples were obtained during each sampling event. One or more VOCs (PCE, CTET, and chloroform) have been detected (excluding false positive results) in 19 (28%) of the 67 samples collected from the well since March 1991. A trace concentration of PCE (0.4 μ g/L) was detected in the groundwater sample collected from the well in December 2002; the last previous sample from this well that contained PCE was collected in May 1997 (1 μ g/L). The occasional detection of very low levels of PCE and other VOCs in the groundwater samples from well GW-144 is of questionable significance with regard to groundwater quality at Kerr Hollow Quarry.

Well GW-544 is located directly south (hydraulically downgradient) of Construction Demolition Landfill VI (Figure A.5). This well, which is completed with a nominal 15-ft screened interval in the middle Knox Group at a total depth of 109 ft bgs, has an uninterrupted 13-year monitoring history that includes quarterly sampling from March 1991 through December 1992 and semiannual sampling from March 1993 through July 2002. These monitoring results show that the well yields calcium-magnesium-bicarbonate groundwater with the nearly equal molar concentrations of calcium and magnesium that are characteristic of uncontaminated groundwater in the Knox Group. However, low levels of chloroform have been detected in each of the groundwater samples collected from the well since February 2000 (1.2 μ g/L), with the highest concentration reported for the sample collected in July 2002 (2.4 μ g/L). Although these chloroform concentrations are very low, they do not appear to be sampling or analytical artifacts because chloroform was not detected in the laboratory blanks and trip blanks associated with these groundwater samples.

Well GW-177 is located at the west end of the CRSP and is completed with a 13-ft monitored interval in the Copper Ridge Dolomite (132-145 ft bgs). The extensive sampling history for this well includes 10 years of continuous quarterly monitoring (February 1986 - February 1996) that spanned the closure of the CRSP in November 1988, along with a five-year sampling gap (March 1996 - March 2001) that spanned the change to low flow sampling in January 1998. Monitoring results show that the well yields calcium-magnesium-bicarbonate groundwater containing a mixture of dissolved VOCs dominated by 111TCA and 11DCA. Both compounds and 11DCE were detected in the groundwater samples collected from the well during CY 2002, with the highest concentrations of each compound reported for the sample obtained in January 2002 (seasonally high flow conditions); note that the maximum concentration of 11DCE exceeds the MCL (Table 32). The presence of these VOCs in this well reflects strike-parallel groundwater transport (or possibly vapor-phase transport) toward a localized depression in the water table located west of the western disposal trenches at the CRSP. Also, the concentrations of the VOCs in the well decreased substantially immediately

after the CRSP were closed and capped, but have subsequently exhibited somewhat divergent concentration trends, with an indeterminate trend for 111TCA (Figure A.49) and increasing trends for 11DCA and 11DCE (see Section 5.3). Both 11DCA and 11DCE are degradation products of 111TCA, possibly indicating the chemical and/or biological degradation in the groundwater.

Traces of 111TCA ($<1~\mu g/L$) were detected in both of the groundwater samples collected during CY 2002 from well GW-796, which is completed with a screened monitored interval in the Copper Ridge Dolomite (122-136 ft bgs) about 500 ft directly south (across geologic strike) of the CRSP (Figure A.5). Similarly low levels of 111TCA ($2~\mu g/L$ or less) were detected in 16 (76%) of the previous 21 groundwater samples collected from the well since the initial sampling in May 1993. The presence of 111TCA in this well reflects downgradient transport from the western trench area at the CRSP (the only confirmed source of 111TCA in the Chestnut Ridge Regime), possibly along "quickflow" conduits described in LMES (1994). This interpretation is supported by: (1) the consistently low dissolved solids in the groundwater samples from the well (e.g., 119 mg/L in January 2002), which implies short groundwater residence time, and (2) the results of falling head permeability tests for the well (1.2 - 4.2 ft/d; Jones 1998) indicate that the monitored interval intercepts highly permeable groundwater flowpaths.

Analytical results for the groundwater samples collected from well GW-798 during CY 2002 support the monitoring data obtained during CY 2001 that confirmed the initial detection of chloroethanes (111TCA and 11DCA), chloroethenes (PCE, TCE, 11DCE, and c12DCE), and TCFM in the samples obtained during CY 2000. The CY 2002 groundwater monitoring results show VOC concentrations in the well ranging from less than 1 μ g/L (TCE) to 11 μ g/L (TCFM), with PCE concentrations in January (5.1 μ g/L) and July 2002 (7.1 μ g/L) that exceed the MCL. This well is located about 1,500 ft east-southeast of the CRSP (Figure A.12), which is the only known source of these VOCs that is hydraulically upgradient of the well. Accordingly, dissolved VOCs in the groundwater at well GW-798 most likely reflect groundwater transport (and/or possibly vapor-phase transport) from the disposal trenches at the CRSP. Moreover, the CY 2002 monitoring results suggest an increasing concentrations trend that potentially reflects a corresponding increase in the relative flux of dissolved VOCs via the groundwater flowpaths monitored by well GW-798 (see Section 5.3).

Monitoring results obtained since January 1992 show that the calcium-magnesium-bicarbonate groundwater in well GW-305, which is located directly south (hydraulically downgradient) of the eastern (unlined) portion of Industrial Landfill IV (Figure A.10), contains relatively low levels of 111TCA, 11DCE, and 11DCA. Each of these compounds was detected in the groundwater samples collected from the well during each quarter of CY 2002, with similar summed concentrations evident in January (37 μ g/L), May (33.1 μ g/L), July (35 μ g/L), and November (35 μ g/L). Along with the historical data for this well, which has been sampled on an uninterrupted quarterly or semiannual basis since March 1990, these monitoring results continue an increasing concentration trend for the VOCs in this well (see Section 5.3).

Although 111TCA, 11DCE, and 11DCA are components of the VOC plume originating from the western disposal trenches at the CRSP, well GW-305 is more than one mile west (upgradient) of the CRSP (Figure A.12) and seasonal groundwater elevations in the well are more than 10 ft higher than in any of the wells at the CRSP (Figure A.10). Consequently, the CRSP seems an unlikely source of the VOCs in well GW-305. Industrial Landfill IV is the only potential contaminant source area that is hydraulically upgradient of the well, but waste disposal records for the landfill, which began receiving wastes in October 1989, do not note the disposal of chlorinated solvents or other wastes with VOCs. Additionally, assuming rapid migration to the saturated zone and unimpeded advective transport in the groundwater, the range of hydraulic conductivity values (0.025 - 0.028 ft/d) indicated by falling head permeability tests in well GW-305 (Jones 1998) do not support transport of 111TCA to the well within the time period (795 to 825 days)

between the initial disposal of waste at Industrial Landfill IV and the first-time detection of 111TCA in the well (January 4, 1992). Thus, the repeated detection of 111TCA and other VOCs in the groundwater samples from the well, despite the apparently low permeability of the flowpaths monitored by the well, suggest that: (1) dissolved VOCs were present in the well before January 1992 but were not detected in the samples collected from the well, perhaps because purging the well for conventional sampling volatilized the compounds; (2) the VOCs are from an unknown source area located very close to the well; or (3) the VOCs migrated from Industrial Landfill IV via a combination of mechanisms (e.g., vapor phase transport) that may greatly increase the rate of transport relative to the groundwater flow rate.

3.3.3 Radioactivity

Most of the monitoring wells in the Chestnut Ridge Regime do not typically yield groundwater samples with elevated gross alpha activity (>15 pCi/L) or gross beta activity (>50 pCi/L) and the CY 2002 monitoring results are consistent with these historical findings. Gross alpha and/or gross beta activity reported for the groundwater samples collected from 28 wells during CY 2002 exceed the corresponding MDAs. The bulk of these results reflect background levels of alpha and beta radioactivity (<5 pCi/L) and are characterized by large proportional counting errors (i.e., a high degree of analytical uncertainty). However, gross beta activity reported for the groundwater samples collected from well GW-205 in July 2002 (85 pCi/L) exceeds the SDWA screening level (50 pCi/L), which is just above the gross beta activity reported for the groundwater sample collected in January 2002 (47 pCi/L). To identify the source of the elevated beta radioactivity in the groundwater at this well, both of these groundwater samples were analyzed for uranium isotopes, Tc-99, and potassium-40 (K-40), which is a beta-emitting isotope that should be present in light of the very high total potassium concentrations in the well (K-40 = 0.0119% of total potassium; Brownlow 1979). Results of these analyses show U-234, U-238, and Tc-99 activities below or just slightly above respective MDAs, whereas the K-40 activities reported for each sample (53 pCi/L and 89 pCi/L, respectively) are consistent with the corresponding gross beta activities. These results seem to confirm K-40 as the source of the elevated beta radioactivity in the (grout-contaminated) groundwater at well GW-205. Moreover, the relationship between elevated potassium and gross beta activity also holds true for other wells with suspected grout contamination, as illustrated by the data in Table 33.

Table 33. Total potassium concentrations and beta radioactivity in wells GW-205, GW-221 and GW-757

A polyto/Units	Background/No Grout Contamination		Suspected Grout Contamination			
Analyte/Units	GW-221		GW-205		GW-757	
	January	July	January	July	January	July
	2002	2002	2002	2002	2002	2002
Potassium mg/L	0.885	1.07	64.8	78	17.7	17.1
Gross beta activity pCi/L	3	3	47	85	15	18

4.0 EXIT PATHWAY/PERIMETER MONITORING DATA EVALUATION

This section contains an evaluation of groundwater and surface water quality in areas where contaminants from sources associated with Y-12 are most likely to migrate beyond the boundaries of the ORR. Separate exit pathway/perimeter monitoring data evaluations are provided for the Bear Creek, East Fork, and Chestnut Ridge hydrogeologic regimes based on the monitoring data obtained from the respective CY 2002 groundwater and surface water monitoring networks. Each evaluation is based on monitoring results that meet the applicable DQOs of the Y-12 GWPP (LMES 2000).

4.1 BEAR CREEK REGIME

The CY 2002 monitoring results and respective historical data for the following monitoring wells, springs, and surface water sampling locations in Bear Creek and selected northern tributaries of the creek serve as the basis for the following evaluation of surface water and groundwater quality where contaminants from Y-12 are most likely to migrate beyond the boundaries of the Bear Creek Regime.

Table 34. Bear Creek Regime CY 2002: sampling locations used for exit pathway/perimeter monitoring

Moni	Monitoring Wells			Surface Water Stations					
Well Number	Monitored Interval Depth (ft bgs)	Springs		Bear (Main C		Bear Creek Tributaries			
GW-712 GW-713 GW-714 GW-715	441.5 - 457.5 305.0 - 315.2 115.1 - 145.0 32.0 - 44.0	SS-1 SS-4 SS-5	SS-6 SS-7 SS-8	BCK-00.63 BCK-03.30 BCK-04.55 BCK-07.87 BCK-09.20	BCK-09.40 BCK-09.47 BCK-11.54 BCK-11.84 BCK-11.97	NT-01 S07 NT-03 NT-07	NT-08 NT-8-E NT-8-W		

For evaluation purposes, the above listed sampling locations are assigned to one of three areas: Upper Bear Creek encompasses the sampling locations upstream (east) of BCK-11.84; Middle Bear Creek encompasses sampling locations between BCK-11.84 and BCK-09.20; and Lower Bear Creek encompasses the sampling locations downstream of BCK-09.20 and the monitoring wells listed above (Figure A.2). Separate evaluations of the exit pathway monitoring data for Upper, Middle, and Lower Bear Creek are provided in the following sections. Each evaluation is focused on the principal components of the groundwater contaminant plumes in the Bear Creek Regime: nitrate, uranium, VOCs, and radioactivity (gross alpha activity and gross beta activity). Note that the monitoring results for the surface water sampling locations in Bear Creek (and its tributaries) are not flow-proportionate and, therefore, do not provide data regarding the relative flux of contaminants in the creek.

4.1.1 Upper Bear Creek

The chemical quality of surface water in Upper Bear Creek is largely controlled by inflow of groundwater containing the primary components of the contaminant plume emplaced during historical operations of the former S-3 Ponds. To the west of this site, highly contaminated groundwater discharges from the aquitard (Nolichucky Shale) as base flow into NT-1, which enters Bear Creek about 2,500 ft downstream of the site.

Also, the highly contaminated groundwater in the Nolichucky Shale extends west of NT-1 (parallel with geologic strike) where it upwells into the shallow flow system, continues westward in the shallow groundwater and ultimately discharges into NT-2, which enters the main channel of Bear Creek about 1,400 ft downstream of its confluence with NT-1 (Figure A.2). In addition to the influx of contaminants from the NT-1 and NT-2 catchments, contaminated groundwater in the Maynardville Limestone discharges into Bear Creek via seeps and springs along the main channel, including spring SS-1. As shown in the following data summary (Table 35), monitoring results obtained during CY 2002 show that nitrate, (total) uranium, and beta radioactivity are the more widespread contaminants in Upper Bear Creek, with VOCs detected only in the samples from the NT-01 sampling station.

Table 35. Upper Bear Creek CY 2002: maximum contaminant concentrations

Sampling	Nitrate	Uranium		VOCs (µg/L)			Radioa (pC	ectivity Ci/)
Point	(mg/L)	(mg/L)	PCE	c12DCE	MC	Chloroform	Alpha	Beta
NT-01 SS-1 S07 (NT-02) BCK-11.97	1,180 18.5 61.2 257	0.132 0.0415 NA 0.151	62	2 J	4 J	2 J	150 29 NA 89	6,000 60 NA 780
Screening Level	10 mg/L	0.03 mg/L	5 μg/L	5 μg/L	Sum	->5 μg/L	15 pCi/L	50 pCi/L
Note: "." = Not dete	Note: "." = Not detected; J = Estimated concentration; NA = Not analyzed							

Titoto Titot detected, V. Estimated concentration, 1417. 1400 data; 200

These results show that contaminant concentrations in surface water from the NT-1 catchment remain very high, with nitrate levels over 1,000 mg/L, total uranium almost an order-of-magnitude above the MCL (0.03 mg/L), and gross beta activity over 5,000 pCi/L. Additionally, these results confirm the sharply higher contaminant concentrations indicated by respective levels of nitrate, PCE, and gross beta activity reported for the surface water samples collected from NT-01 in January 2001 (81.7 mg/L, 8 μ g/L, and 230 pCi/L) and July 2001 (1,110 mg/L, 62 μ g/L, and 4,400 pCi/L).

The CY 2002 monitoring results for sampling station S07 show that nitrate concentrations in the surface water at NT-02 are much lower than evident in NT-01 but nonetheless remain substantially above the 10 mg/L MCL (Table 35). Radiological analyses of selected surface water samples collected by the WRRP during CY 2002 confirm that the high levels of beta radioactivity in the surface water at S07 are from Tc-99, although the Tc-99 activity evident in March 2002 (94 pCi/L) is much lower than reported for the sample collected from S07 in September 2001 (487 pCi/L).

In addition to inflow of contaminants from the NT-1 and NT-2 catchments, the quality of surface water in the upper reach of Bear Creek is affected by contaminated groundwater that is discharged into the creek from spring SS-1, which is directly south of the confluence of Bear Creek and NT-1 (Figure A.3). Monitoring results obtained during CY 2002 show elevated levels of nitrate, uranium, and radioactivity (alpha and beta) in the spring, with similar levels of each contaminant (e.g., nitrate) reported for the samples collected from the spring in January (18.5 mg/L) and July 2002 (17.4 mg/L).

Monitoring results for sampling station BCK-11.97, which is immediately downstream of the confluence of Bear Creek and NT-2 (Figure A.2), reflect the combination of contaminant inflows from the NT-1 and NT-02 catchments and from seeps and springs in the Maynardville Limestone that discharge into the upstream reach of the creek. As illustrated by the results for nitrate, contaminant concentrations in the surface water at BCK-11.97 exhibit wide seasonal fluctuations (Figure A.50), with the highest concentrations typically evident during the seasonally dry periods of the year (summer and fall) when groundwater discharge sustains the bulk

of the baseflow in the creek (DOE 1997a). Note that the nitrate concentration reported for the surface water sample collected in July 2002 (257 mg/L) is an order-of-magnitude higher than evident in February 1997 (25.3 mg/L) and is the highest nitrate level detected at this sampling location since November 1990 (308 mg/L). Also, results of radiological analyses of the surface water samples collected at BCK-11.97 during CY 2002 show that the beta radioactivity is primarily from Tc-99, with substantially higher Tc-99 activity in July 2002 (1,500 pCi/L) compared to January 2002 (400 pCi/L). Interestingly, these samples did not have widely different levels of uranium isotopes, which are the primary source of alpha radioactivity in Upper Bear Creek, with nearly equal levels of U-234 (26 pCi/L and 25 pCi/L) and U-238 (46 pCi/L and 43 pCi/L) evident in January and July 2002.

Based on the preceding evaluation, the quality of groundwater and surface water in Upper Bear Creek continues to be strongly impacted by contamination associated with historical waste disposal activities in BCV. Nevertheless, contaminant concentrations reported for surface water samples collected during CY 2002 are substantially lower than historical levels evident in Upper Bear Creek.

4.1.2 Middle Bear Creek

Surface water quality in Middle Bear Creek is impacted by a mixture of contaminants from the former S-3 Ponds (nitrate, uranium, and radioactivity), the former Boneyard/Burnyard/HCDA (uranium and VOCs), and the BCBG WMA (uranium, VOCs, and radioactivity). Also, results of a study by the U.S. Geological Survey show that much of Middle Bear Creek loses flow to the Maynardville Limestone, particularly the section of the channel immediately south of the Oil Landfarm WMA (Robinson and Mitchell 1994). This section of the main channel of Bear Creek plays an important role in transferring contaminants from the creek into the groundwater system (DOE 1997a). As shown in Table 36, elevated concentrations of at least one of the principal groundwater contaminants in the Bear Creek Regime were reported for each of the CY 2002 exit pathway/perimeter sampling locations (arranged in sequence from upstream to downstream) in Middle Bear Creek except NT-03.

Table 36. Middle Bear Creek CY 2002: maximum contaminant concentrations

Sampling	Nitrate	Uranium	VOCs (µg/L)			Radioactivity (pCi/L)			
Point	(mg/L)	(mg/L)	PCE	тсе	c12DCE	11DCE	VC	Alpha	Beta
BCK-11.84	88.8	0.109						NA	222
NT-03	0.02	NA						NA	NA
BCK-11.54	61.2	0.145						NA	159
SS-4	43.7	0.182		20	17	2 J		73	180
NT-07	0.11	0.0154	28	23	85	3 J	3	NA	NA
NT-8-E	0.13	1.16			2 J			NA	NA
NT-8-W	0.03	0.016						NA	NA
NT-08	0.05	0.361	11	6	66	1 J	1 J	NA	NA
BCK-09.47	23.4	0.205	2 J	1 J	14			NA	76
BCK-09.40	19.4	0.204	2 J	2 J	21			80	120
SS-5	16.6	0.109		2 J	3 J			48	81
BCK-09.20	15.9	0.121			2 J			NA	50
Screening Level	10 mg/L	0.03 mg/L	5 μg/L	5 μg/L	70 μg/L	7 μg/L	2 μg/L	15 pCi/L	50 pCi/L

Note: "." = Not detected; J = Estimated concentration; NA = Not analyzed

These data show that the quality of surface water in the upstream reach of Middle Bear Creek, as illustrated by the CY 2002 monitoring results for the BCK-11.84 and BCK-11.54 sampling stations, continues to be strongly impacted by contaminants from the former S-3 Ponds, notably nitrate, uranium, and beta radioactivity (Tc-99). This is clearly illustrated by the CY 2002 monitoring data, which show elevated levels of nitrate at each of the BCK sampling locations on the main channel of Middle Bear Creek compared to the background levels of nitrate (<1 mg/L) in each of the northern tributaries of Middle Bear Creek (Table 36).

The CY 2002 monitoring results for the BCK-11.84 and BCK-11.54 sampling stations illustrate the fairly sharp decrease in the concentrations of S-3 Ponds contaminants in Bear Creek that occurs downstream of the confluence with NT-3. For instance, the maximum CY 2002 nitrate concentration (61.2 mg/L) and gross beta activity (159 pCi/L) at BCK-11.54 are about 50% lower than the corresponding maximum nitrate concentration (98.8 mg/L) and gross beta activity (298 pCi/L) at BCK-11.84. This at least partially reflects dilution via inflow of surface water from the NT-3 catchment, which enters Bear Creek immediately downstream of BCK-11.84 (Figure A.2). Moreover, removal of the radiological wastes from the Boneyard/Burnyard in the spring of CY 2002 (see Section 2.5.1.2) appears to have substantially reduced the level of uranium isotopes (and elemental uranium) in NT-3, as indicated by the U-234 and U-238 activities reported for the surface water samples collected from the NT-03 sampling station in March 2002 (18 pCi/L and 31 pCi/L, respectively) and September 2002 (2 pCi/L and 4 pCi/L, respectively).

Discharge of contaminated groundwater from springs SS-4 and SS-5 sustains flow in Bear Creek during seasonally low flow periods (summer and fall) and contributes to surface water contamination downstream of BCK-11.97 (DOE 1997a). As shown on Table 36, the monitoring results obtained during CY 2002 show that both springs continue to discharge groundwater with elevated levels of nitrate, uranium, and radioactivity (alpha and beta). Samples collected from each spring during CY 2002 also contained VOCs, including TCE concentrations in spring SS-4 that exceed the MCL (Table 36). As in previous years, contaminant concentrations in the groundwater samples from spring SS-4 are higher than respective levels reported for the samples from spring SS-1, which is hydraulically upgradient (and upstream) and about a mile closer to the former S-3 Ponds (Figure A.2). Higher concentrations in the groundwater discharged from spring SS-4 probably reflect transfer of contaminants from Bear Creek into the Maynardville Limestone via the losing reach of the creek south of the Oil Landfarm (DOE 1997a).

The CY 2002 monitoring data for the BCK sampling stations in Middle Bear Creek that are downstream of the confluence of Bear Creek and the northern tributaries (NT-7 and NT-8) that drain the bulk of the BCBG WMA (Figure A.3) illustrate the inflow of dissolved VOCs from sources within NT-7 and NT-8 catchments. Moreover, the CY 2002 monitoring results for sampling station NT-07 are distinguished by surprisingly high levels of VOCs (considering the potential for volatilization), including maximum concentrations of PCE, TCE, c12DCE, and VC that exceed respective MCLs (Table 36). These compounds also were detected at generally lower concentrations in the surface water samples collected from station NT-08, with PCE and TCE concentrations above respective MCLs (Table 36). Flow in both tributaries is sustained by discharge of groundwater containing dissolved VOCs associated with the waste disposal trenches within BG-C East and BG-C West (DOE 1997a), which were covered with low-permeability caps during the RCRA closure of the BCBG WMA. Also, groundwater containing dissolved VOCs discharges into NT-8 somewhere along its main channel between the NT-8-E sampling station and the confluence of with Bear Creek (Figure A.2), as indicated by the much lower concentrations of VOCs at this sampling station compared to VOC levels evident farther downstream at the NT-08 sampling station (Table 36). Inflow of uranium-contaminated surface water from the NT-8 catchment contributes to the elevated concentrations of uranium in Bear Creek at BCK-09.47, where uranium levels are higher than evident at any of upstream sampling locations along Middle Bear Creek (Table 36).

The quality of surface water in Middle Bear Creek at the BCK-09.47 and BCK-09.40 sampling stations is impacted by inflow of contaminated surface water (and groundwater) from NT-7 and NT-8, which enters Bear Creek upstream of BCK-09.47, and the inflow of contaminated groundwater from springs SS-4 and SS-5, which discharge from the south side of Bear Creek upstream of BCK-09.20 (Figure A.2). Inflow from the NT-7 and NT-8 catchments contributes to the relatively low levels of VOCs detected in the samples from both BCK-09.47 and BCK-09.40. Elevated nitrate concentrations at BCK-09.47, BCK-09.40, and BCK-09.20 are probably sustained by downstream transport from Upper Bear Creek, augmented by nitrate-contaminated groundwater discharged from springs SS-4 and SS-5. As illustrated by data for BCK-09.40 (Figure A.50), nitrate concentrations in Middle Bear Creek show seasonal concentration fluctuations and a relatively indeterminate long-term concentration trend.

Monitoring results obtained during CY 2002 show that the concentrations of total uranium in Bear Creek at the BCK-09.47, BCK-09.40, and BCK-09.20 sampling stations exceed the MCL by almost an order-of-magnitude (Table 36). Elevated uranium concentrations at these Bear Creek sampling stations primarily reflect downstream transport of uranium leached from the former Boneyard/Burnyard (and discharged into the creek from NT-3) combined with inflow of uranium contaminated surface water from the NT-8 catchment and uranium-contaminated groundwater discharged into the creek from springs SS-4 and SS-5. Thus, the excavation and removal of the radiological wastes from the former Boneyard/Burnyard during CY 2002 (see Section 2.5.1.2) is expected to substantially reduce the level of elemental and isotopic uranium in Bear Creek downstream of NT-03. Analytical results for the surface water samples collected during CY 2002 from BCK-09.20, which is about 7,400 ft downstream of the confluence of NT-03 and Bear Creek, show U-234 (14 pCi/L) and U-238 (30 pCi/L) activities in March 2002 (before the removal of the wastes) that are slightly higher than the respective activities (11 pCi/L and 19 pCi/L) in September 2002 (after removal of the wastes).

Results of the radiological analyses of selected samples collected from Middle Bear Creek during CY 2002 also reflect contamination from a combination of sources in the Bear Creek Regime. As illustrated by the results of radiological analyses of surface water samples collected from BCK-11.84, BCK-11.54, BCK-09.47, and BCK09.20 on March 11, 2002, summarized below in Table 37, a mixture of uranium isotopes (and associated decay products) and Tc-99 account for the alpha and beta radioactivity evident at the sampling stations along Middle Bear Creek.

Table 37. Results of radiological analyses of surface water samples collected from Middle Bear Creek in March 2002

Radioanalyte	Activity (pCi/L)					
	BCK-11.84	BCK-11.54	BCK-09.47	BCK-09.20		
U-234 U-238	19 ± 4 30 ± 6	18 ± 4 31 ± 6	17 ± 4 44 ± 10	14 ± 3 30 ± 6		
Tc-99 Th-234*	$\begin{array}{ccc} 403 & \pm & 8 \\ 30 & \pm & 6 \end{array}$	235 ± 6 31 ± 6	181 ± 6 44 ± 10	$\begin{array}{ccc} 70 & \pm & 5 \\ 30 & \pm & 6 \end{array}$		
Note: * Assuming equ	Note: * Assuming equilibrium with U-238					

The uranium isotopes are probably from sources in the BCBG, primarily via influx from the NT-8 catchment, and the former Boneyard/Burnyard, but the detection of Tc-99 in these samples confirm transport from the contaminant plume emplaced during operation of the former S-3 Ponds.

Based on the preceding evaluation of the CY 2002 exit pathway/perimeter monitoring data, the quality of groundwater and surface water in Middle Bear Creek is significantly impacted by inorganic, organic, and radiological contaminants associated with past operations at Y-12.

4.1.3 Lower Bear Creek

As shown in the following data summary (Table 38), the CY 2002 monitoring results for the Lower Bear Creek sampling locations (arranged in sequence from upstream to downstream) show elevated concentrations of nitrate, uranium, gross alpha activity, and gross beta activity reported for a few of the Lower Bear Creek sampling locations exceed respective screening levels.

Table 38. Lower Bear Creek CY 2002: maximum contaminant concentrations

	Nitrate Uranium		Summed VOCs	Radioactivity (pCi/L)			
Sampling Point	(mg/L)	(mg/L)	(μg/L)	Gross Alpha	Gross Beta		
GW-712	0.034			2.13	5.73		
GW-713				16	40		
GW-714	1.7			3	6.1		
GW-715	4.2	0.043		18	40		
BCK-07.87	17	0.153		62	110		
SS-7	1.9	0.0161		NA	9.29		
SS-8	0.29			NA	2.71		
BCK-04.55	6.69	0.0568		21	32		
BCK-03.30	4.1	0.0345		NA	16		
BCK-00.63	2.82	0.0242		9	15		
Screening Level	10 mg/L	0.03 mg/L	MCL or Sum >5 μg/L	15 pCi/L	50 pCi/L		
Note : ":" = not dete	Note: "." = not detected; NA = not analyzed						

Exit Pathway Picket W monitoring wells GW-712, GW-713, GW-714, and GW-715 are completed with screened or open-hole monitored intervals at various depths within different hydrostratigraphic zones along a strike-normal transect across the Maynardville Limestone (and lower Knox Group) about 5,000 ft west of the BCBG WMA (Figure A.2). Monitoring results obtained during CY 2002 show that the deeper wells (GW-712 and GW-713) continue to yield uncontaminated, sulfate-enriched (>50% of total anions) groundwater. However, elevated levels of gross alpha activity (16 pCi/L) and gross beta activity (40 pCi/L) were reported for the groundwater sample collected from well GW-713 in July 2002 and similarly elevated gross alpha and gross beta activities were reported for the groundwater sample collected from this well in July 2001. However, these elevated alpha and beta activities may reflect analytical interferences, possibly associated with the relatively high dissolved solids in the groundwater samples from this well (e.g., 367 mg/L in July 2002), because the most likely potential sources of the alpha and beta radioactivity in the groundwater at this well, uranium isotopes (and associated decay products) and Tc-99, were not detected (i.e., did not exceed the MDA) in the associated groundwater samples.

Monitoring results obtained during CY 2002 show that nitrate concentrations in the groundwater at Exit Pathway Picket W monitoring wells GW-714 and GW-715 exceed background levels (<1 mg/L) but remain below the MCL (Table 36). Considering the location of these wells relative to the main channel of Bear Creek and the extensive hydrologic interaction between surface water in the creek and groundwater in the

Maynardville Limestone, localized recharge of nitrate-contaminated surface water may explain the nitrate levels in the groundwater at these wells. This interpretation is supported by the groundwater elevations in wells GW-714 and GW-715, which show vertically downward hydraulic gradients (e.g., 0.013 in July 2002) and potentially indicate that the nearby sections of Bear Creek may locally lose flow to the shallow karst network in the Maynardville Limestone.

Total uranium concentrations reported for the groundwater samples collected from well GW-715 during CY 2002 are at least two-orders-of-magnitude above background levels, with the concentration evident in July 2002 (0.043 mg/L) exceeding the previous high for the well (0.0194 mg/L in January 2000) and the MCL (0.03 mg/L). As with nitrate in the shallow groundwater at this well, the elevated uranium concentrations in the well probably reflect localized recharge of contaminated surface water in Bear Creek. Additionally, uranium concentrations reported for the groundwater samples collected from the well since January 2000 are substantially higher than indicated by previous sampling results (e.g., <0.004 mg/L in July 1999). Increasing concentrations of uranium in the shallow groundwater at this well my indicate a temporal increase in the relative flux of uranium along the groundwater flowpaths monitored by the well or may be an artifact of the change from conventional sampling to low-flow sampling. As shown in Table 39, summary statistics determined from the respective conventional sampling (1992-1997) and low-flow sampling (1998-2002) results (excluding non-detect results) indicate that groundwater samples obtained with the latter method have significantly higher and more variable uranium concentrations.

Table 39. Summary statistics for uranium concentrations in well GW-715

	Total uranium (mg/L)			
Summary Statistic	Conventional Sampling (12 Samples)	Low-Flow Sampling (7 Samples)		
Maximum	0.002	0.043		
Minimum	0.00059	0.0006		
Mean	0.001	0.016		
Standard Deviation	0.0004	0.014		

Intrinsic differences between the conventional and low-flow sampling methods may explain the disparity between the respective uranium results. The low-flow sampling method induces groundwater inflow from the water-producing interval(s) nearest to the intake of the dedicated bladder pump in each well. In well GW-715, the pump intake is located just below the midpoint of the monitored interval, which generally coincides with the location of a water-producing solution cavity that was encountered 37.6 - 38.6 ft bgs during installation of the well (BWXT 2003b). Thus, the groundwater samples obtained with the low-flow sampling method may be representative of uranium-contaminated groundwater that enters the well via this solution cavity, which may be hydraulically connected with surface water in Bear Creek. Conversely, purging the well for conventional sampling probably induces inflow of groundwater from all of the water-producing features within the monitored interval, including those that may transmit uncontaminated groundwater into the well and effectively dilute the concentration of uranium (and other contaminants) in the groundwater samples obtained with this sampling method.

The CY 2002 monitoring results show the highest levels of nitrate, uranium, gross alpha activity, and gross beta activity in Lower Bear Creek occur at the BCK-07.87 sampling station, which is near the confluence of Bear Creek and NT-11 (Figure A.2). These results show that nitrate concentrations, uranium levels, and alpha radioactivity exceed respective MCLs and that gross beta activity exceeds the SDWA screening level (Table 38). Alpha radioactivity is from uranium isotopes and radiological analyses of the surface water

samples collected during CY 2002 show seasonal fluctuations, with the highest levels of U-234 (18 pCi/L) and U-238 (44 pCi/L) reported for the sample collected in January 2002 (seasonally high flow conditions). Beta radioactivity is from a combination of Th-234 (assuming equilibrium with U-238) and Tc-99, which was detected at 75 pCi/L in January 2002 and 21 pCi/L in July 2002. These monitoring results suggest transport of Tc-99 from the former S-3 Ponds combined with influx of uranium isotopes from sources associated with the former Boneyard/Burnyard and/or the BCBG WMA.

Downstream of BCK-07.87, the monitoring results obtained during CY 2002 show that elevated concentrations of uranium in Bear Creek occur at BCK-04.55 and BCK-03.30 (Table 38). In addition to the elevated total uranium concentrations, radiological analyses of the surface water samples from each of these sampling stations show low levels of U-234 (4 - 8 pCi/L) and U-238 (4 - 17 pCi/L). The presence of the uranium isotopes explains the elevated gross alpha activity at BCK-04.55 (21 pCi/L). As illustrated by data for BCK-04.55, the levels of gross alpha activity in Lower Bear Creek generally mirror the seasonal fluctuations evident in Upper and Middle Bear Creek, with the CY 2002 monitoring results continuing a relatively indeterminate long-term trend (Figure A.50).

Based on the preceding evaluation of the CY 2002 exit pathway/perimeter monitoring data, contaminants associated with Y-12 continue to impact the quality of surface water in Lower Bear Creek, and contaminant concentrations are generally consistent with historical levels evident in Lower Bear Creek.

4.2 EAST FORK REGIME

As shown in Table 40, the CY 2002 monitoring results reported for 12 monitoring wells and ten surface water sampling locations were evaluated for the purposes of exit pathway/perimeter monitoring in the East Fork Regime.

Table 40. East Fork Regime CY 2002: sampling locations for exit pathway/perimeter monitoring

	Monitor		e Water g Locations		
Well Number	Monitored Interval Depth (ft bgs)	Well Number	Monitored Interval Depth (ft bgs)	UEFPC	North of Pine Ridge
GW-151 GW-207 GW-208 GW-220 GW-722 GW-733	85.0 - 110.0 100.0 - 109.6 404.0 - 412.8 31.0 - 45.2 75.0 - 644.3 240.1 - 256.5	GW-735 GW-744 GW-747 GW-750 GW-816 GW-832	67.5 - 79.2 55.0 - 69.5 67.4 - 79.6 61.2 - 72.7 2.9 - 15.8 4.0 - 11.8	OF 200 STATION 8 OF 51 LRSPW STATION 17	GHK2.51ESW GHK2.51WSW NPR07.0SW NPR12.0SW NPR23.0SW

The monitoring wells are located in the eastern Y-12 area, hydraulically downgradient (north/northeast or east/southeast) of NHP/Lake Reality, and all but two of the wells (GW-151 and GW-220) are located within 500 ft of the ORR boundary along Scarboro Road (Figure A.3). The surface water sampling stations in UEFPC include two outfalls (OF 51 and OF 200) and a surface water sampling station (Station 8) in the central Y-12 area, the outfall of the UEFPC distribution channel underdrain (LRSPW), and a surface water station downstream of Lake Reality (Station 17) near Bear Creek Road (Figure A.3). In addition to these surface water sampling locations within the East Fork Regime, analytical results reported for the surface water samples collected during CY 2002 from five sampling stations (GHK2.51ESW, GHK2.51WSW,

NPR07.0SW, NPR12.0SW, and NPR23.0SW) located in unnamed drainage features north of Pine Ridge along the ORR Boundary also serve the exit pathway/perimeter monitoring purposes of DOE Order 5400.1.

As shown in Table 41, elevated concentrations of one or more of the principal groundwater contaminants in the East Fork Regime were reported for at least one of the groundwater samples collected during CY 2002 from five of the exit-pathway monitoring wells and for at least one of the surface water samples from two outfalls and three UEFPC sampling stations.

Table 41. East Fork Regime CY 2002: types of contaminants detected at the exit pathway/perimeter sampling locations

Sampling Location	Type of Contaminant		
	Inorganics	VOCs	Radioactivity
Groundwater			
GW-151		•	•
GW-220		•	•
GW-722		•	•
GW-733		•	
GW-832		•	
Surface Water			
OF 200	•	•	
STATION 8	•	•	•
OF 51	•	•	
LRSPW	•	•	
STATION 17	•	•	

The following sections provide separate evaluations of the CY 2002 monitoring data for these wells and surface water sampling stations.

4.2.1 Groundwater

At least one of the groundwater samples collected during CY 2002 from exit-pathway wells GW-151, GW-220, GW-722, GW-733, and GW-832 contained summed concentrations of dissolved VOCs of at least 5 ug/L and, as shown below in Table 42, the maximum concentrations of PCE, TCE, and CTET that exceed respective MCLs.

Table 42. East Fork Regime CY 2002: maximum VOC concentrations in exit pathway/perimeter monitoring wells

XX7 11	Maximum Concentration (μg/L)				
Well	PCE	TCE	CTET		
GW-151 GW-220	500 310	120 61	1,500 1,200		

Table 42. (Continued)

W 11	Maximum Concentration (μg/L)					
Well	PCE	TCE	CTET			
GW-722-22	13	2 J	97			
GW-722-20	77	6	390			
GW-722-17	11	2 J	150			
GW-722-14	10	2 J	160			
GW-733			10			
GW-832	4 J		9			
MCL (µg/L)	5	5	5			
Note: "." = Not detected; J = Estimated concentration						

Well GW-832 is located next to the UEFPC distribution channel near the southeast corner of Lake Reality (Figure A.3). This shallow well (12 ft bgs) intercepts the gravel underdrain beneath the UEFPC distribution channel and, in May 1995, served as the pumping well for a short-term pumping test that demonstrated a direct hydraulic connection between the well and the Lake Reality Sump (see Section 2.4.1). Historical monitoring data show that well GW-832 yields sulfate-enriched (>30 mg/L) calcium-magnesium-bicarbonate groundwater that contains a mixture of dissolved VOCs dominated by CTET, chloroform, and PCE. Each of these compounds were detected in the groundwater samples collected from the well during CY 2002 and, as shown in Table 42, the maximum concentration CTET exceeds the MCL. Results for these compounds are consistent with historical data for the well and reflect an indeterminate long-term concentration trend for PCE, as illustrated by the PCE concentrations evident in May 1996 (6 μ g/L), August 1999 (6 μ g/L), and August 2002 (4 μ g/L), and a decreasing concentration trend for CTET, as illustrated by the CTET results reported for the groundwater samples collected from the well in August 1999 (44 μ g/L), July 2001 (17 μ g/L) and August 2002 (6 μ g/L). Decreasing concentrations of CTET in the shallow groundwater at well GW-832 may be attributable to groundwater withdrawals from the extraction well (GW-845) for the CERCLA East End VOC Plume Intercept Action.

Wells GW-151 and GW-220 are clustered in the lower Maynardville Limestone about 200 ft directly east (hydraulically downgradient) of NHP and about 400 ft south-southeast (across geologic strike) of well GW-832 (Figure A.3). Historical data show that wells GW-151 and GW-220, which are completed at respective depths of about 110 ft bgs (bedrock interval) and 45 ft bgs (water table interval), yield calcium-magnesium-bicarbonate groundwater containing a mixture of dissolved VOCs dominated by CTET and PCE. The CY 2002 monitoring results show that summed VOC concentrations exceed 2,000 μ g/L in the groundwater at well GW-151, with maximum concentrations of PCE, TCE, and CTET remaining substantially above respective MCLs (Table 42). Similar concentrations of these VOCs were reported for well GW-220, with summed VOC concentrations above 1,000 μ g/L and maximum concentrations of PCE, TCE, and CTET that exceed respective MCLs. These monitoring results also continue the increasing long-term concentration trends indicated by the respective historical VOC data for wells GW-151 and GW-220 (see Section 5.2).

Well GW-722 is located about 700 ft southeast of wells GW-151 and GW-220 and approximately 350 ft west of the ORR boundary (Figure A.3). This well is completed with a 500 ft open-hole interval in the Maynardville Limestone and, as noted previously, has a multiport sampling system that enables collection of discrete groundwater samples from multiple depths. Groundwater samples were collected from ten

sampling ports (numbered in ascending order from deepest to shallowest) during each quarter of CY 2002; the depth of these sampling ports is shown on Figure A.4. Trace levels ($<1~\mu g/L$) of VOCs were detected in the groundwater samples from sampling ports 6 (560 ft bgs), 10 (500 ft bgs), 30 (151 ft bgs), 32 (107 ft bgs), and 33 (87 ft bgs). Benzene ($0.2~\mu g/L$) was detected in a sample from port 6, ETB ($0.3~\mu g/L$) was detected in a sample from Port 30, and chloroform ($1~\mu g/L$ or less) was detected in samples from ports 32 and 33. Considering the very low concentrations of these VOCs and the sporadic detection in the groundwater samples from these sampling ports, many of these results may be analytical artifacts. Also, natural occurring petroleum hydrocarbons at depth in the bedrock potentially explains the low levels ($0.5~-4~\mu g/L$) of benzene, DMB, ETB, toluene, and styrene (a degradation product of ETB) that have been detected repeatedly in the groundwater samples collected from port 26 (216 ft bgs), including all four of the samples obtained during CY 2002. Nevertheless, the hydrocarbons could possibly be from a anthropogenic source, although the closest known source in the Maynardville Limestone (Tank 2331-U in the central Y-12 area) is at least 3,000 ft from well GW-722. Also, petroleum hydrocarbons are generally not present in the other wells of shallow and intermediate depth in the Maynardville Limestone that are hydraulically upgradient to the west (along geologic strike) of well GW-722.

As illustrated by the data summarized in Table 42, substantially higher individual and summed VOC concentrations ($>100\,\mu\rm g/L$) were reported for the groundwater samples collected from well GW-722 sampling ports 14, 17, 20, and 22. These results are consistent with historical data for these sampling ports, which are believed to monitor the center of mass of the VOC plume within the intermediate and deep intervals of the Maynardville Limestone hydraulically downgradient to the east (parallel with geologic strike) of groundwater extraction well GW-845 (DOE 2002). Full-time operation of the extraction well began in October 2000 and the summed concentrations of VOCs detected in the groundwater samples from the deeper ports (14 and 17) appear to have decreased substantially in response (Figure A.51).

Well GW-733 is located about 125 ft southeast (across geologic strike) of well GW-722 (Figure A.3) and is completed at a depth of 256 ft bgs in the upper Maynardville Limestone. Historical monitoring results show that well GW-733 yields calcium-magnesium-bicarbonate groundwater samples that infrequently contain trace levels ($<5~\mu g/L$) of several chloroethenes (primarily PCE) along with relatively low concentrations ($<50~\mu g/L$) of chloromethanes (primarily CTET). Low levels of CTET and chloroform were detected in the groundwater samples collected from the well during CY 2002. These results show that although the CTET concentrations in the well exceed the MCL (Table 42), they remain substantially lower than the CTET levels evident during the early 1990s (e.g., 67 $\mu g/L$ in August 1992). Also, the concentrations of CTET detected during CY 2002 continue the relatively indeterminate trend evident since the late 1990s, as illustrated by the CTET results reported for the groundwater samples collected from the well in March 1998 (11 $\mu g/L$), July 1999 (8 $\mu g/L$), January 2000 (3 $\mu g/L$), July 2001 (10 $\mu g/L$), and January 2002 (10 $\mu g/L$). This CTET concentration trend does not indicate any response to the operation of groundwater extraction well GW-845, which is located about 600 ft northwest of well GW-733.

Based on the preceding evaluation of the CY 2002 exit pathway/perimeter monitoring data, groundwater contamination from operations at Y-12 continue to extend into Union Valley beyond the boundary of the ORR. However, VOC concentrations in the groundwater from intermediate depths in the Maynardville Limestone hydraulically downgradient to the east (along geologic strike) of groundwater extraction well GW-845 have decreased substantially in response to the full time operation of the well.

4.2.2 Surface Water

As shown in Table 43, one or more of the primary contaminants associated with Y-12 were detected in at least one of the surface water samples collected during CY 2002 from five UEFPC sampling stations in the East Fork Regime (listed in order from farthest upstream to farthest downstream).

Table 43. East Fork Regime CY 2002: maximum contaminant concentrations at the UEFPC exit pathway/perimeter sampling locations

G II D i i	Nitrate Uranium (mg/L)		Summed VOCs	Radioactivity (pCi/L)	
Sampling Point			(µg/L)	Alpha	Beta
OF 200	7.7	0.12	17	NA	NA
STATION 8	2.7	0.04	11	16.72	8.96
OF 51	4.9	0.00892	54	4.27	4.89
LRSPW	1.49	0.0119	22	8.8	10
STATION 17	2.5	0.0281	5	NA	NA
Screening Level	10 mg/L	0.03 mg/L	>5 μg/L	15 pCi/L	50 pCi/L
Note: "•" = not detected; NA = not analyzed					

Note that the monitoring results are not flow-proportionate and, therefore, do not provide data regarding the relative flux of the contaminants in UEFPC.

Although less than the MCL, the CY 2002 maximum nitrate concentrations for the surface water sampling stations in UEFPC exceed background levels (<1 mg/L), with the highest concentration (7.7 mg/L) reported for the sample collected from OF 200 in February 2002 (i.e., seasonally high flow conditions). Also, the CY 2002 monitoring results for OF 200 and Station 8 show that uranium concentrations in UEFPC within the central Y-12 area (i.e., upstream of Lake Reality) exceed the MCL (Table 43), with the highest concentration reported for the samples collected from each location in February 2002.

One or more VOCs were detected in at least one of the surface water samples collected during CY 2002 from each of the UEFPC exit pathway/perimeter sampling stations, with the highest concentrations reported for OF 51 (Table 43), which is located in the central Y-12 area near the southeast corner of Building 9201-2 (Figure A.3). Most results for these VOCs are estimated values ($<5 \mu g/L$) below the respective analytical reporting limits, but the maximum concentrations of PCE ($24 \mu g/L$) and TCE ($10 \mu g/L$) reported for OF 51 and the maximum concentration of CTET reported for the LRSPW ($14 \mu g/L$) exceed respective MCLs. Also, for each sampling location, the summed and individual VOC concentrations detected in the samples obtained during seasonally dry flow conditions are higher than the concentrations of VOCs detected in the samples obtained during seasonally wet flow conditions, as illustrated by the summed VOC concentrations for the surface water samples collected from OF 51 in February ($12 \mu g/L$) and September 2002 ($24 \mu g/L$).

Results for gross alpha activity and gross beta activity that exceed the corresponding MDA were reported for at least one of the surface water samples collected during CY 2002 from Station 8, OF 51, and the LRSPW (Table 43). Most of these results are characterized by large proportional counting errors (i.e., a high degree of analytical uncertainty) and reflect background levels of radioactivity. However, gross alpha activity slightly above the MCL (15 pCi/L) was reported for the surface water sample collected from Station 8 in February 2002 (16 pCi/L). Analytical results obtained during CY 2002 indicate that the alpha radioactivity

in UEFPC at Station 8 is from uranium isotopes, with the highest U-234 (3 pCi/L) and U-238 (9 pCi/L) activities evident in February 2002.

Based on the preceding evaluation of the CY 2002 exit pathway/perimeter monitoring data, operations at Y-12 continue to impact the quality of surface water in UEFPC upstream of the ORR boundary.

4.3 CHESTNUT RIDGE REGIME

The CY 2002 monitoring results reported for the springs and surface water sampling stations listed below in Table 44 were evaluated for the purposes of DOE Order 5400.1 exit pathway/perimeter monitoring in the Chestnut Ridge Regime.

Table 44. Chestnut Ridge Regime CY 2002: sampling locations used for exit pathway/perimeter monitoring

GROUND	WATER	SURFACE WATER		
SCR1.25SP SCR3.5SP	SCR4.3SP SCR5.2SP	SCR1.5SW SCR2.2SW SCR4.4SW	MCK 2.0 MCK 2.05	

The following sections describe separate evaluations of the CY 2001 monitoring results for these groundwater and surface water sampling locations.

4.3.1 Groundwater

The springs used for exit pathway/perimeter monitoring in the Chestnut Ridge Regime are located in the primary surface drainage features that traverse the southern flank of Chestnut Ridge, exit the ORR, and discharge into the Melton Hill Reservoir south of Bethel Valley Road (Figure A.5). The CY 2002 monitoring results for these springs are consistent with respective historical data and show that the springs discharge calcium-magnesium-bicarbonate groundwater characterized by a wide range of calcium:magnesium ratios; variable but generally low molar proportions (<10%) of chloride, potassium, sodium, and sulfate; and low concentrations of several trace metals, notably barium, iron, manganese, and strontium.

Monitoring results for most of the springs in the Chestnut Ridge Regime that were sampled during CY 2002 reflect background levels of the primary inorganic groundwater contaminants associated with operations at Y-12. However, the nitrate concentrations reported for the samples collected from spring SCR5.2SP in February (5.43 mg/L) and July 2002 (3.16 mg/L) exceed background levels (<1 mg/L) in uncontaminated surface water in the regime. Although substantially below the drinking water MCL (10 mg/L), these elevated nitrate concentrations possibly reflect transport of nitrate leached from the sewer sludge application sites located within the drainage basin upstream of the spring, which discharges into the unnamed tributary (SCR5) that drains the eastern sections of the Chestnut Ridge Regime.

Volatile organic compounds were not detected in the groundwater samples collected from the springs used for exit-pathway/perimeter monitoring in the Chestnut Ridge Regime during CY 2002. Gross alpha or gross beta activity above the associated MDA was reported only for samples from springs SCR1.25SP, SCR4.3SP, and SCR3.5SP. Each of these gross alpha and gross beta results are low values (<5 pCi/L) with large

proportional counting errors (i.e., a high degree of analytical uncertainty) and are indicative of natural background radiation.

Based on the preceding evaluation of the CY 2002 exit pathway/perimeter monitoring data, operations at Y-12 do not appear to have extensively impacted the quality of groundwater discharged from natural springs located in the surface drainage features that traverse the Chestnut Ride Regime and exit the ORR.

4.3.2 Surface Water

As shown on Figure A.5, the surface water sampling locations used for exit pathway/perimeter monitoring purposes in the Chestnut Ridge Regime during CY 2002 are located in Dunaway Branch (SCR1.5SW) at the western boundary of the regime; in an unnamed tributary east of Industrial Landfill II (SCR2.2SW); in McCoy Branch downstream of the Filled Coal Ash Pond (FCAP) (MCK 2.05 and MCK 2.0); and in the unnamed tributary (SCR4.4SW) that drains the central part of the regime near Industrial Landfill V and Construction/Demolition Landfill VI (Figure A.5).

Analytical results for the surface water samples collected from McCoy Branch during CY 2002 indicate contamination downstream of the FCAP at MCK 2.0 and MCK 2.05 (Figure A.5). These surface water sampling stations are located upstream (MCK 2.05) and downstream (MCK 2.0) of the FCAP Discharge Treatment Wetland, which was constructed as part of the CERLCA remedial action specified in the ROD for the site (DOE 1996). Samples from MCK 2.05 are representative of FCAP "influent" to the wetland and samples from MCK 2.0 are representative of "effluent" from the wetland (DOE 2002). Historical data show that the surface water samples from both locations are distinguished by elevated concentrations of sulfate and arsenic. Sulfate concentrations in the samples collected from both sampling locations during CY 2002 exceed background levels, with the highest concentrations reported for samples collected from MCK 2.0 (42 mg/L) and MCK 2.05 (41.8 mg/L) in February 2002 (seasonally wet flow conditions). Similarly, the monitoring results obtained during CY 2002 show that maximum arsenic concentrations at MCK 2.0 (0.0144 mg/L) and MCK 2.05 (0.0559 mg/L) exceed the former (0.05 mg/L) and proposed federal MCL (0.01 mg/L). Moreover, historical data show that total arsenic concentrations at both sampling locations generally have remained above the MCL since sampling began in February 1998 (Figure A.52).

Monitoring results for the other surface water stations in the Chestnut Ridge Regime that were sampled during CY 2002 reflect background levels of the primary inorganic contaminants associated with Y-12. Similarly, VOCs were not detected in the samples collected from the any of surface water stations. Also, low levels of gross alpha activity or gross beta activity that just exceed the associated MDA were reported for the surface water samples collected from MCK 2.0, MCK 2.05, SCR1.5SW, SCR2.2SW, and SCR4.4SW. Most of these results are characterized by large proportional counting errors (i.e., a high degree of analytical uncertainty) and are indicative of natural background radiation.

Based on the preceding evaluation of the CY 2002 exit pathway/perimeter monitoring data, operations at Y-12 have impacted surface water quality in McCoy Branch near the FCAP, but do not appear to have significantly affected surface-water quality in the other drainage features that traverse the Chestnut Ridge Regime, exit the ORR, and discharge into Melton Hill Reservoir.

5.0 GROUNDWATER QUALITY TREND EVALUATION

This section presents an evaluation of groundwater quality trends at Y-12 that is based on analysis of the monitoring results for CY 2002 sampling locations in the Bear Creek Regime, East Fork Regime, and Chestnut Ridge Regime that exhibit increasing contaminant concentration trends. Evaluation of the contaminant concentration trends for most of these sampling locations is based on time-series plots of the monitoring data obtained since January 1990; a few of the plots include monitoring results obtained during the late 1980s. Data that do not meet applicable DQOs of the Y-12 GWPP were excluded from the trend evaluations.

5.1 BEAR CREEK REGIME

Most of the monitoring wells and springs in the Bear Creek Regime that were sampled during CY 2002 yield uncontaminated groundwater. Of the wells that do monitor contaminated groundwater, most exhibit indeterminate or decreasing long-term contaminant concentration trends (Table B.4). However, as shown below in Table 45, increasing long-term contaminant concentration trends are indicated by the monitoring data for 14 of the CY 2002 sampling locations.

Table 45. Bear Creek Regime CY 2002: sampling locations with increasing contaminant concentration trends

Sampling Location			Increasing Long-Term Concentrations			
Number	Aquitard	Aquifer	Inorganics	VOCs	Radioactivity	
GW-008	•			•		
GW-061		•			•	
GW-071	•			•		
GW-072	•			•		
GW-082	•			•		
GW-085	•		•		•	
GW-537	•				•	
GW-627	•			•		
GW-653	•		•	•		
GW-695		•	•	•	•	
GW-703		•	•	•	•	
GW-706		•	•	•		
GW-715		•	•	•	•	
SS-4		•		•		

The CY 2002 monitoring results for well GW-008 (Nolichucky Shale water table interval) continue the increasing concentration trends for PCE and TCE (Figure A.53), with the groundwater sample collected from the well in July 2002 having the highest concentration of PCE (89 μ g/L) and TCE (11 μ g/L) since January 2000 (PCE = 75 μ g/L and TCE = 3 μ g/L). Increasing concentrations of PCE and TCE in the well potentially reflect temporal increases in the overall flux of dissolved VOCs originating from the southernmost disposal plots at the Oil Landfarm.

The CY 2002 monitoring results for well GW-061 indicate that gross alpha activity in the groundwater at this well exceeds the MCL (15 pCi/L) and is much higher than indicated by historical data for the well, which was

last sampled in September 1995 (Figure A.54). However, because the gap in the sampling history for the well spans the transition from conventional sampling to low flow sampling, the increasing trend may be an artifact of the sampling method, with higher gross alpha activity reported for the groundwater samples obtained with the latter method.

The CY 2002 monitoring results for well GW-071 (Nolichucky Shale intermediate bedrock interval) show substantially higher concentrations of benzene, 11DCE, and 11DCA than indicated by historical data for the well, which was last sampled in June 1991 (Figure A.55). Although the long gap in the sampling history for this well spans the transition from conventional sampling to low flow sampling, the higher concentrations now evident for these VOCs does not appear to be related to the sampling method because similar concentrations of other compounds in the well were reported for samples obtained with each method. This is clearly illustrated by the nearly equal (total) 12DCE concentrations reported for the groundwater samples obtained from conventional sampling in March 1991 (43 μ g/L) and from low flow sampling in March 2002 (44 μ g/L). Moreover, assuming a heterogeneous mixture of VOCs in the groundwater at the well, it is not clear how the sampling method may influence the concentrations of some compounds and not others. Thus, it is not clear if the higher concentrations of benzene, 11DCE, and 11DCA are sampling artifacts or if they reflect an increase in the relative flux of these compounds via the groundwater flowpaths monitored by the well. Moreover, increasing concentrations of 11DCE and 11DCA may occur from the chemical or biological degradation of 111TCA in the groundwater at this well.

The concentrations of 11DCA detected in the groundwater samples collected from well GW-072 (Nolichucky Shale shallow bedrock interval) during CY 2002 are substantially higher than indicated by historical data for the well, which was last sampled in June 1991, with the concentration evident in August 2002 (130 μ g/L) being the highest ever detected in the well (Figure A.56). As with well GW-071, the long gap in the sampling history for well GW-072 spans the change from conventional sampling to low flow sampling and there are not any clear differences between the concentrations of other VOCs detected in the samples obtained with either method. Thus, it is not clear if the higher concentrations of 11DCA are sampling artifacts or if they reflect an increase in the relative flux of 11DCA along the groundwater flowpaths monitored by the well.

Along with the other low-flow sampling results obtained from well GW-082 (Maryville Limestone shallow bedrock interval) since June 1998, the CY 2002 monitoring results continue the increasing concentration trends evident for 12DCE and VC (PCE degradation products), 11DCA and chloroethane (111TCA degradation products), and benzene (Figure A.57). As noted in Section 3.1.1.2, the groundwater in the well exhibits geochemical conditions suitable for the biotic degradation of chlorinated hydrocarbons, and these increasing concentration trends potentially reflect a corresponding change in the relative rate of degradation. Also, increases in the concentrations of these compounds may indicate concurrent increases in their flux via the groundwater flowpaths monitored by the well.

The CY 2002 monitoring results for nitrate and gross beta activity in well GW-085 (Nolichucky Shale shallow bedrock interval) continue what appears to be another temporal "pulse" in the relative flux of nitrate and Tc-99 (the source of the beta radioactivity) in the shallow flow system west of the former S-3 Ponds (Figure A.58). Nitrate concentrations in the well, for example, increased between May 1991 (115 mg/L) and October 1993 (312 mg/L), subsequently decreased through March 1998 (43 mg/L), and again increased through July 2003 (233 mg/L); the trend for gross beta activity generally mimics that of nitrate. Wide temporal changes in the relative flux of Tc-99 in the Nolichucky Shale at well GW-085 may correspond with the episodic disposal of Tc-99 wastes at the former S-3 Ponds.

Along with historical data, the CY 2002 gross beta results for well GW-537 (Nolichucky Shale water table interval) show significant temporal fluctuations (some of which probably reflect analytical variability), but

continue a clearly increasing long-term trend (Figure A.59). As noted in Section 3.1.1.3, the beta radioactivity is from Tc-99 in the shallow groundwater at this well, and the contaminant plume emplaced in the Nolichucky Shale during operations of the former S-3 Ponds is the source of the Tc-99. Consequently, increasing Tc-99 activity in the shallow groundwater at well GW-537 potentially reflect the continued westward migration of the center of mass of the contaminant plume (DOE 1997a).

The concentrations of VOCs detected in the groundwater samples collected from well GW-627 (Nolichucky Shale deep bedrock interval) during CY 2002, as illustrated by the data for PCE, continue the increasing concentration trend evident since the initial detection of PCE in February 1990 (Figure A.60). As noted in Section 3.1.2.1, the well has an extensive sampling history and the analytical results show significant differences between the concentrations of VOCs in groundwater samples obtained with the conventional sampling and low-flow sampling methods. Nevertheless, separate plots of the conventional sampling and low flow sampling results show increasing trends for PCE (Figure A.61), which suggests a continuing increase in the relative flux of PCE (and other VOCs) along strike-parallel flowpaths more than 250 ft bgs in the Nolichucky Shale west of BG-A South.

The CY 2002 monitoring results for well GW-653 (Nolichucky Shale water table interval) continue the widely fluctuating but generally increasing concentration trend for 12DCE evident since early 1993 (Figure A.61). Although the historical data for this well reflect substantial differences between conventional sampling and low-flow sampling results, with significantly higher 12DCE concentrations detected in samples obtained with the latter method, separate plots of the respective 12DCE data show increasing concentration trends. Also, the conventional sampling results reflect substantially more temporal variability and a less strongly increasing trend than the low-flow sampling results. It is not clear if the more steeply increasing concentration trend indicated by the low-flow sampling results is an artifact of the sampling method or if it reflects a corresponding increase in the flux of 12DCE via the flowpaths monitored by the well.

Monitoring results obtained for Exit Pathway Picket B well GW-695 (Maynardville Limestone shallow bedrock interval) during CY 2002 continue the increasing trends evident for nitrate and beta radioactivity (Figure A.62). Nitrate levels in this well increased steadily from 1 mg/L in June 1991 to 10 mg/L in February 1994, generally remained near 10 mg/L through January 2000, and have exceeded 10 mg/L since July 2000. Results for gross beta activity obtained over this same time period likewise reflect an increase from near 10 pCi/L during the early and mid-1990s to 50 pCi/L (the SDWA screening level for gross beta activity) in January 2003. Increasing nitrate concentrations and beta radioactivity in the groundwater at this well reflects a temporal increase in the overall flux of nitrate and Tc-99 (from the former S-3 Ponds) via the groundwater flowpaths monitored by well GW-695.

The CY 2002 monitoring results for Exit Pathway Picket B well GW-703 (Maynardville Limestone intermediate bedrock interval) continue the widely fluctuating but generally increasing trend for gross beta activity (Figure A.63). Moreover, the gross beta activity reported for the samples collected from the well in January (62 pCi/L) and July 2002 (62 pCi/L) represent the highest levels detected in the well. The source of the beta radioactivity in the groundwater at this well is Tc-99, which has been detected (i.e., >MDA) in each of the groundwater samples collected from the well since January 2001, including the samples obtained in January (66 pCi/L) and July 2002 (62 pCi/L). Thus, the increasing gross beta activity in the groundwater at this well reflects a temporal increase in the overall flux of Tc-99 (from the former S-3 Ponds) along the groundwater flowpaths monitored by the well.

The concentrations of TCE detected in the groundwater samples collected from Exit Pathway Picket B well GW-706 (Maynardville Limestone intermediate bedrock interval) during CY 2002 continue a generally increasing long-term concentration trend (Figure A.64). Additionally, the TCE data for this well indicate

cyclic (seasonal) concentration fluctuations, with a series of "peak" concentrations evident in September 1992 (15 μ g/L), December 1994 (16 μ g/L), February 1999 (20 μ g/L), January 2000 (19 μ g/L), January 2001 (20 μ g/L), and March 2003 (17 μ g/L). Data for other contaminants in the well, such as nitrate, exhibit similarly cyclic concentration fluctuations but do not reflect increasing long-term trends.

Total uranium concentrations reported for the groundwater samples collected from Exit Pathway Picket W well GW-715 (Maynardville Limestone water table interval) during CY 2002 continue an apparently increasing trend evident since January 2000, with the uranium concentration evident in July 2002 (0.043 mg/L) being the highest ever reported for the well (Figure A.65). Increasing concentrations of uranium in the groundwater at this well indicate a temporal increase in the relative flux of uranium from one or more upgradient source areas, including the commingled groundwater contaminant plume in the Maynardville Limestone. A generally concurrent increase in the level of alpha radioactivity in the well also suggests an increase in the relative flux of uranium isotopes along the groundwater flowpaths monitored by the well (Figure A.65). Nevertheless, the repeated detection of uranium and gross alpha activity in the groundwater samples from well GW-715 generally coincides with the change from conventional sampling to low flow sampling. For example, gross alpha activity above the MDA (and associated CE) was reported only for one of the 14 groundwater samples collected from the well with the conventional sampling method, whereas six of the ten groundwater samples obtained with the low-flow sampling method had gross alpha activity above the associated MDA (and associated CE).

The CY 2002 monitoring results for spring SS-4 generally continue the increasing TCE concentration trend indicated by historical data, with the TCE concentration detected in the groundwater sample collected from the spring in July 2002 ($20\,\mu g/L$) being the highest ever reported for the spring (Figure A.66). Data obtained since January 1996, which is when samples began to be obtained from the mouth of the spring (samples were previously collected at the point where the groundwater from the spring entered Bear Creek), show that the TCE concentrations fluctuate widely, with the lowest concentrations typically evident during high flow conditions when recharge dilutes the baseflow of contaminated groundwater discharged from the spring. Increasing concentrations of TCE potentially reflect a corresponding increase in the relative flux of TCE in the shallow karst network connected with spring SS-4.

5.2 EAST FORK REGIME

Most of the monitoring wells in the East Fork Regime that were sampled during CY 2002 yield uncontaminated groundwater. Of the wells that monitor contaminated groundwater, most show indeterminate or decreasing long-term contaminant concentration trends (Table B.5). However, as shown below in Table 46, increasing concentration trends are evident for one or more of the primary contaminants detected in the groundwater samples collected from 12 wells during CY 2002.

Table 46. East Fork Regime CY 2002: sampling locations with increasing contaminant concentration trends

Monitoring Well			Increasing Long-Term Concentrations		
Number	Aquitard	Aquifer	Inorganics	VOCs	Radioactivity
GW-108	•				•
GW-151		•		•	
GW-154		•	•	•	•

Table 46. (Continued)

Monitoring Well			Increasing Long-Term Concentrations		
Number	Aquitard	Aquifer	Inorganics	VOCs	Radioactivity
GW-220		•		•	
GW-223		•	•	•	
GW-253		•		•	
GW-383	•			•	
GW-606		•	•		
GW-633	•			•	
GW-698		•		•	
GW-762	•			•	
GW-769	•		•	•	

As shown on Figure A.67, Tc-99 activity in the groundwater at well GW-108 (Nolichucky Shale water table interval) increased sharply between November 1996 (8,690 pCi/L) and February 1999 (25,100 pCi/L), decreased slightly through January 2000 (18,117 pCi/L), and increased again through January 2002 (29,525 pCi/L). The cyclic nature of the long-term trend for Tc-99 activity may be indicative of temporal changes in the relative flux of Tc-99 related to the intermittent disposal of "slugs" of Tc-99 wastes at the former S-3 Ponds.

The CY 2002 monitoring results for wells GW-151 and GW-220 (Maynardville Limestone shallow bedrock interval) east of NHP continue the increasing concentrations of CTET and PCE indicated by the historical data for each well (Figure A.68). Monitoring results for these wells show fairly steady concentration increases following the initial detection of VOCs in February 1986 (GW-151) and August 1988 (GW-220). The subsequent increase in CTET and PCE concentrations in these wells may result from a combination of reduced recharge following closure of NHP and the strong local hydrologic influence of the UEFPC distribution channel underdrain (DOE 1998). Also, the increasing trend evident for well GW-151 may be at least partially attributable to the change in the groundwater sampling method because the samples obtained from with the low-flow sampling method have substantially higher VOC concentrations than the samples obtained with the conventional sampling method. It is possible that the higher VOC concentrations now evident in these wells also may be related to the full-time operation of groundwater extraction well GW-845.

Monitoring results obtained during CY 2002 indicate increasing concentrations of total uranium along with increasing levels of gross alpha activity in the groundwater at well GW-154 (Maynardville Limestone water table interval), with the gross alpha activity (1,270 pCi/L) evident in July 2002 being the highest reported for the well (Figure A.69). Although there are two significant gaps in the sampling history for the well (May 1991 - October 1994 and December 1996 - January 1999), the available data indicate that the uranium concentrations and gross alpha activity generally increased following closure of NHP (and the associated Oil Skimmer Basin). Closure of NHP also appears to have reversed the vertical hydraulic gradients indicated by the groundwater elevations in wells GW-154 and GW-223, with the upward gradients evident before closure of the site changing to downward gradients after closure of the site (see Figure A.70). Also, the groundwater samples with the highest uranium concentrations and gross alpha activity were collected after the full-time operation of groundwater extraction well GW-845.

The CY 2002 monitoring results for well GW-223 (Maynardville Limestone shallow bedrock interval) continue the increasing concentration trends for total uranium and 12DCE (Figure A.70). Concentrations of both contaminants increased in response to the closure of NHP (and the associated Oil Skimmer Basin), as

illustrated by the order-of-magnitude increase in the concentration of uranium between August 1989 (0.002 mg/L) and September 1999 (0.0236 mg/L). Increasing concentrations of these contaminants also coincide with the reversal in the vertical hydraulic gradients from upward before closure of NHP to the downward after closure of the site (Figure A.70). Moreover, although the CY 2002 monitoring results show that the levels of uranium and 12DCE in the groundwater at well GW-223 remain much higher than indicated by historical data, the concentrations of both contaminants now may be decreasing in response to the operation of groundwater extraction well GW-845. For instance, the concentration of 12DCE (95 μ g/L) detected in the groundwater sample collected from well GW-223 in October 2000, shortly after groundwater began to be pumped full-time from well GW-845, is at least 80% higher than the 12DCE concentrations evident in January (44 μ g/L) and August 2002 (52 μ g/L).

The CY 2002 monitoring results for well GW-253 (Maynardville Limestone water table interval) continue the increasing concentrations of PCE degradation products in the well, notably 12DCE and VC (Figure A.71). The significance of these upward trends is not clear. If the increasing concentrations result from biodegradation, concurrent decreases in the concentrations of the parent compounds (PCE and TCE) would be expected. However, as noted in Section 3.1.2.2, indeterminate concentration trends are evident for PCE and TCE in the well. Thus, the concentrations of these parent compounds may be maintained by dissolution of DNAPL potentially present in the subsurface near the S-2 Site (DOE 1998).

The CY 2002 monitoring results for well GW-383 (Nolichucky Shale water table interval) are consistent with the widely fluctuating but generally increasing concentrations of PCE (Figure A.72). Increasing levels of PCE in the well potentially reflect greater relative flux of dissolved VOCs via the groundwater flowpaths monitored by the well. Nevertheless, the PCE concentration detected in the groundwater sample collected from the well in August 2002 (380 μ g/L) is the lowest detected in the well since June 1999 (360 μ g/L) and is almost 50% lower than the PCE concentration evident in October 2002 (640 μ g/L). This potentially indicates a response to the operation of groundwater extraction well GW-845.

The CY 2002 monitoring results for well GW-606 (Maynardville Limestone intermediate bedrock interval) suggest an increasing trend for nitrate (Figure A.73). Indeed, the nitrate concentration evident in July 2002 (12 mg/L) exceeds the MCL (for the first time) and is almost double the next highest concentration (6.3 mg/L in July 2000). However, higher nitrate concentrations coincide with the change from conventional sampling to low-flow sampling; none of the groundwater samples obtained with the conventional sampling had nitrate concentrations above 2 mg/L whereas the nitrate levels in all of the groundwater samples obtained with the low-flow sampling method exceed 2 mg/L. Along with the higher nitrate concentrations, the low-flow sampling results also suggest grout contamination in the well, as indicated by the substantial increase in pH (from 8.3 in March 1998 to 10.61 in January 2002) and potassium concentrations (from 3.4 mg/L in March 1998 to 12.1 mg/L in January 2002). Redevelopment of the well in June 2002 (three well volumes of groundwater were pumped from the well) and appears to have alleviated the grout contamination, as indicated by the lower pH (7.96) and potassium concentration (4.27 mg/L) evident in July 2002, but also may have induced greater inflow of nitrate into the well.

Monitoring results obtained for well GW-633 (Nolichucky Shale water table interval) during CY 2002 show that the concentrations of several VOCs in the highly contaminated groundwater at this well, as illustrated by the results for benzene and PCE, are substantially higher than indicated by historical data (Figure A.74). However, because the sampling history for this well spans the change from conventional sampling to low flow sampling, it is not clear if the higher benzene and PCE concentrations are artifacts of the sampling method or if they reflect increased flux of each compound via the flowpaths monitored by the well. Alternatively, the higher concentrations of benzene and PCE may reflect a substantial change in the

subsurface environment which may have effectively slowed or stopped the biodegradation of these compounds.

The CY 2002 monitoring results for well GW-698 (Maynardville Limestone shallow bedrock interval) continue a generally increasing concentration trend evident for c12DCE, with the concentration evident in November 2002 (43 μ g/L) being the highest ever detected in the well (Figure A.75). Increasing concentrations of c12DCE may reflect an increase in the relative rate of PCE biodegradation in the groundwater at this well, which would likewise account for the apparent decrease in the concentration of PCE in the well (see Section 3.2.2.2).

The CY 2002 monitoring results for well GW-762 (Nolichucky Shale shallow bedrock interval), which has a long gap in its sampling history (May 1995 - February 1999) that spans the change from conventional sampling to low-flow sampling, show that the concentrations of PCE, TCE, and 11DCE remain substantially higher than evident in the early 1990s (Figure A.76). For example, the TCE concentration evident in July 2002 (150 μ g/L) is almost 400% higher than the TCE concentration evident in February 1993 (38 μ g/L). The significance of these concentration trends with respect to the relative flux of VOCs along the flowpaths intercepted by the well is not clear from the available data. Also, interpretation of the trends is complicated by the biodegradation of the dissolved VOCs in the groundwater at this well (see Section 3.2.1.2).

The CY 2002 monitoring results for well GW-769 (Nolichucky Shale shallow bedrock interval) continue the sharply higher CTET concentrations that have become evident since April 2000 (Figure A.77). For instance, previous monitoring results show that CTET concentrations in the well remained near 10 μ g/L through October 1999 (7 μ g/L) before jumping to 25 μ g/L in April 2000. Additionally, the long-term trend for PCE appears to show cyclic concentration fluctuations, with the highest concentrations typically evident during seasonally low flow conditions. This too appears to be the case for CTET because the groundwater samples collected from the well during seasonally low flow conditions typically contain the highest CTET concentrations, as illustrated by the CTET results reported for the samples obtained in October 2000 (75 μ g/L), October 2001 (73 μ g/L), and October 2002 (160 μ g/L).

5.3 CHESTNUT RIDGE REGIME

Almost all of wells in the Chestnut Ridge Regime that were sampled during CY 2002 yield uncontaminated groundwater. Of the few wells that yield contaminated groundwater, most show decreasing contaminant concentration trends (Table B.6). As discussed below, however, increasing concentrations of one or more VOCs are indicated by the groundwater monitoring results for wells GW-177, GW-305, and GW-798.

As noted in Section 3.3.2, the groundwater in the Knox Group at well GW-177 contains a mixture of dissolved chloroethenes that originate from westernmost disposal trenches at the Security Pits and the CY 2002 monitoring results indicate an increasing concentration trend for 11DCE (Figure A.78). Although this upward trend warrants continued monitoring, it may be of questionable significance considering that the 11DCE concentrations have not exceeded $10\,\mu\text{g/L}$ in any of the groundwater samples collected from this well, including samples collected before closure of the Security Pits.

As illustrated on Figure A.79, the monitoring results for Industrial Landfill IV well GW-305 reflect: (1) the initial detection of 111TCA in January 1992 (0.6 μ g/L) and subsequent concentration increase through July 2000 (26 μ g/L) followed by a slight concentration decrease through November 2002 (18 μ g/L); (2) the initial detection of 11DCA in July 1996 (1 μ g/L) and subsequent concentration increase through January 2002

 $(15 \,\mu\text{g/L})$; and (3) the initial detection of 11DCE in January 1997 (1 $\mu\text{g/L}$) and the subsequent detection of low levels ($<5 \,\mu\text{g/L}$) of the compound in 15 of the 17 groundwater samples subsequently collected from the well, including three of the four samples obtained during CY 2002. The sequential detection of 111TCA, 11DCA, and 11DCE in the well suggest the arrival of the parent compound (111TCA) followed by the arrival of related degradation products (11DCA and 11DCE) several years later. As noted in Section 3.3.2, the source of the VOCs in the groundwater at well GW-305 has not been confirmed, but the detection and subsequent increase in the concentrations of 111TCA, 11DCA, and 11DCE most likely reflect groundwater transport (and possibly vapor-phase transport) from Industrial Landfill IV, which is the only potential source area that is hydraulically upgradient of the well.

As noted in Section 3.3.2, the low levels of dissolved chloroethenes (PCE, 12DCE, and 11DCE) detected in the groundwater samples collected from well GW-798 during CY 2002 continue an increasing concentration trend evident after the initial detection of PCE in January 2000 (Figure A.80). Moreover, the initial detection of PCE was followed by the first-time detection of 12DCE and 11DCE in July 2000, with the concentrations of all three compounds in July 2002 being the highest detected in the well. These results indicate groundwater transport (and possibly vapor phase transport) of these compounds from the plume of dissolved VOCs originating from the disposal trenches at the Security Pits, which is the only potential source area that is hydraulically upgradient of well GW-798.

6.0 CONCLUSIONS AND RECOMMENDATIONS

The groundwater and surface water quality data obtained during CY 2002 are generally consistent with: (1) the presence of contaminants from known and suspected source areas in the Bear Creek Regime, East Fork Regime, and Chestnut Ridge Regime; (2) the types of contaminants from respective source areas in each regime and the overall pattern and extent of contaminant transport in each regime; and (3) the long-term contaminant concentration trends evident for the respective groundwater and surface water sampling locations in each regime, including increasing concentration trends that may reflect increased contaminant flux.

Based on the detailed evaluation of the CY 2002 groundwater and surface water monitoring data, the following actions are recommended:

- In order to confirm the apparent sensitivity to the groundwater sampling method, "paired" groundwater samples should be collected from wells GW-229, GW-686, and GW-698 on consecutive days, with the low-flow sampling method used the first day and the conventional sampling method used the next.
- Well GW-170 in Union Valley and wells GW-205 and GW-757 should be redeveloped to reduce the apparent grout contamination in each well. Also, in order to ensure collection of the most representative (i.e., least grout-contaminated) groundwater samples from these wells, the conventional sampling method should be considered or, if the low-flow sampling method is used, each well should be purged until the pH is below 9 before the groundwater samples are obtained.
- The GWPP should discontinue laboratory analyses for pH, specific conductance, and turbidity. Field measurements of pH and specific conductance are more representative than the laboratory data and the turbidity results are redundant with results for total suspended solids.

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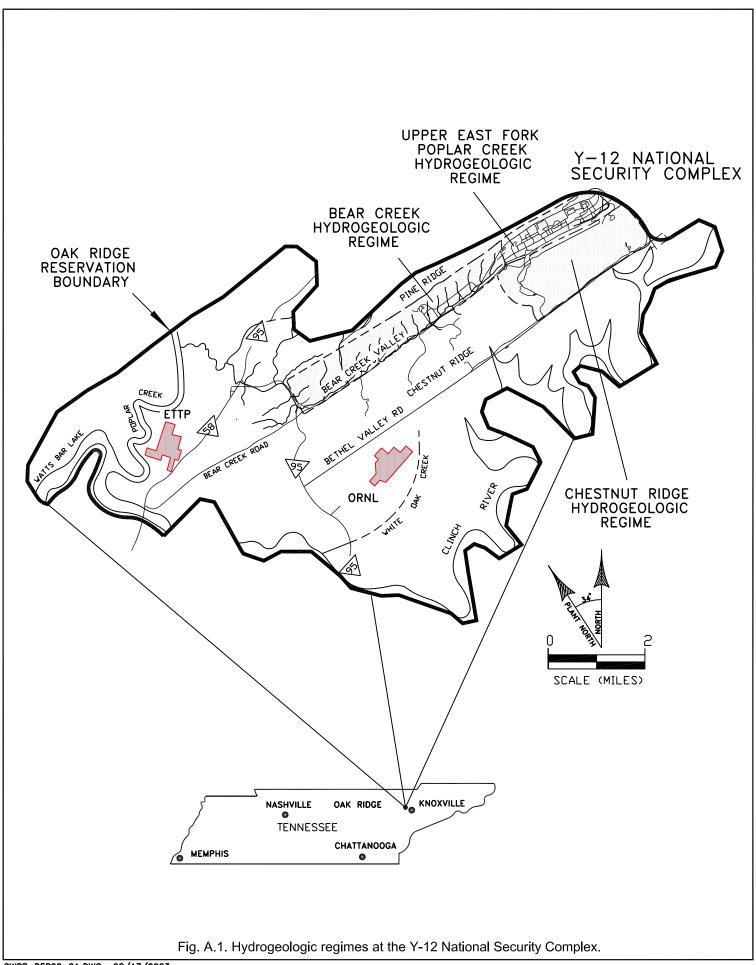
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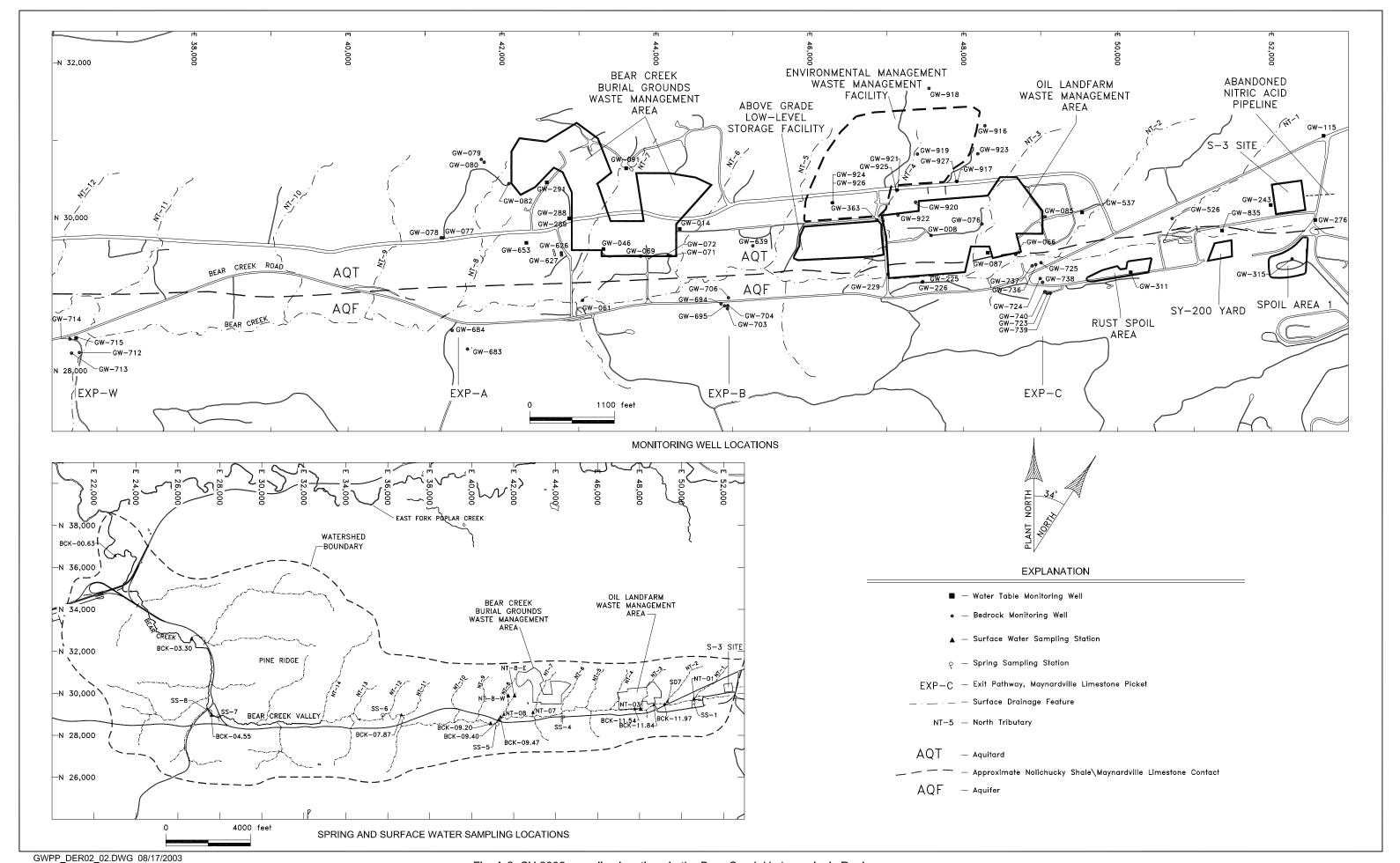
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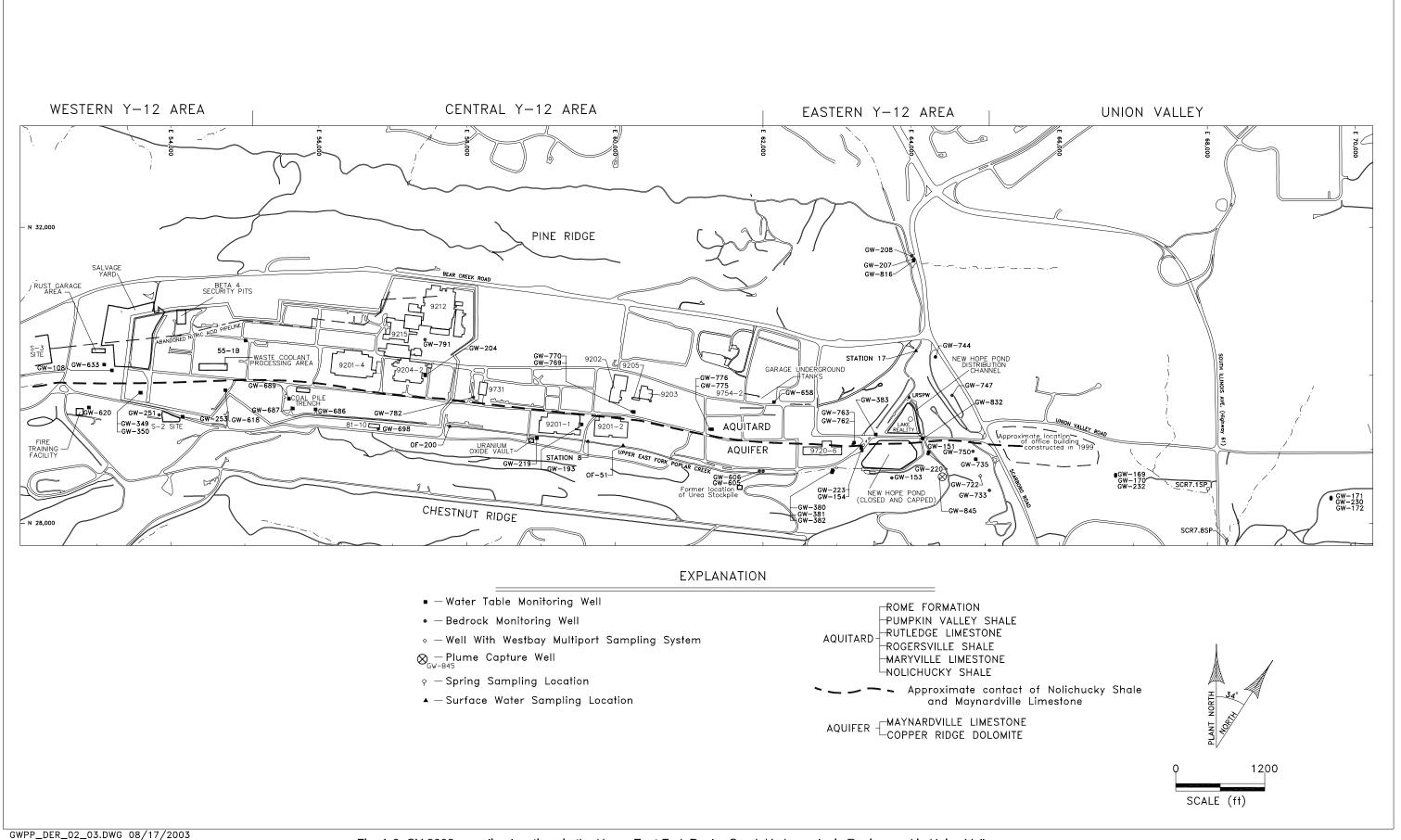
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APPENDIX A

FIGURES







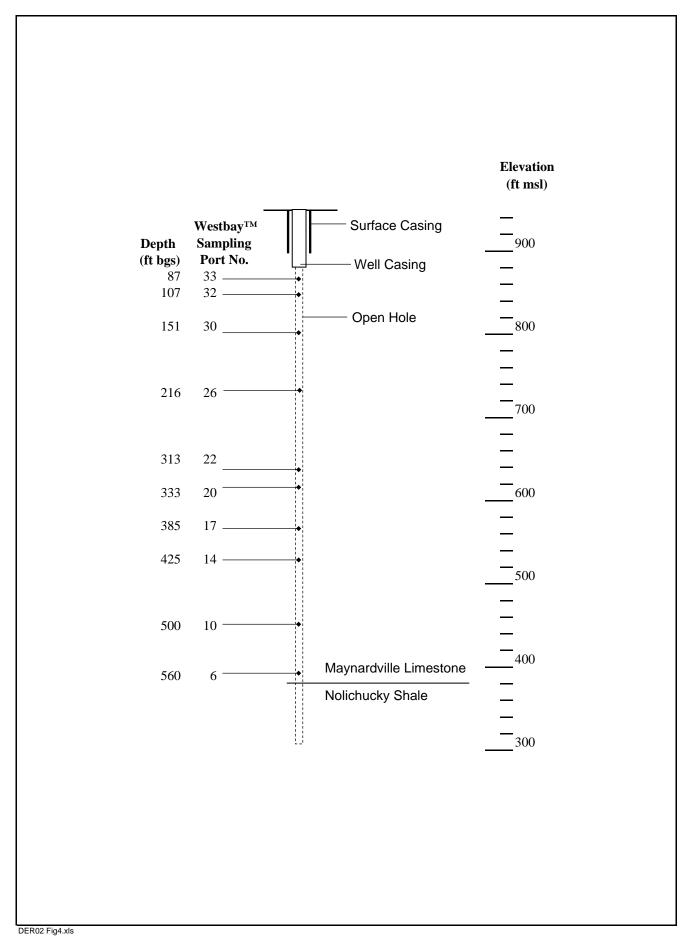
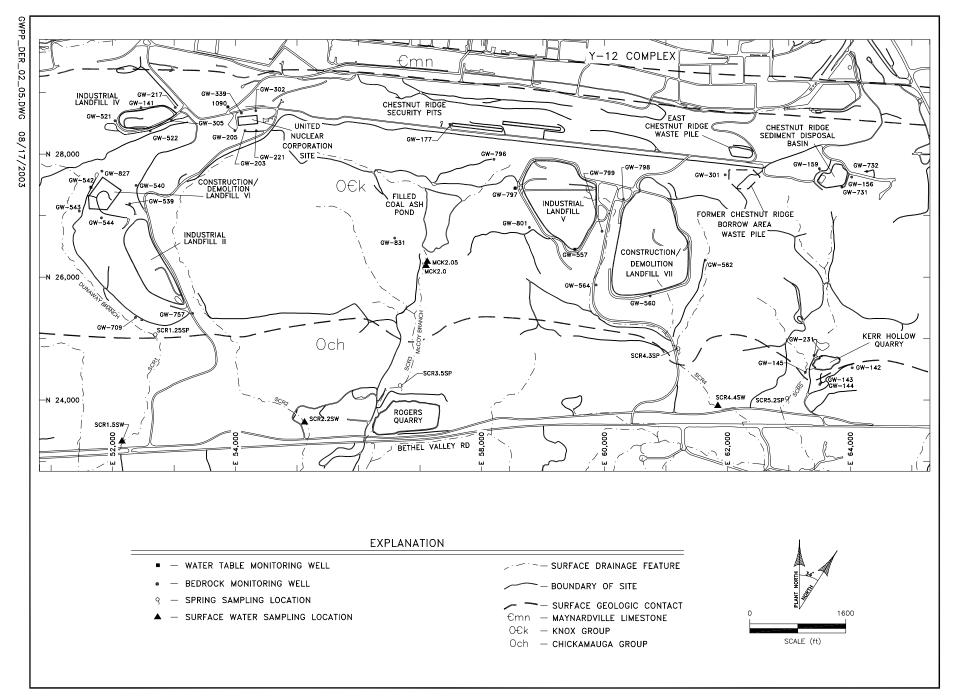
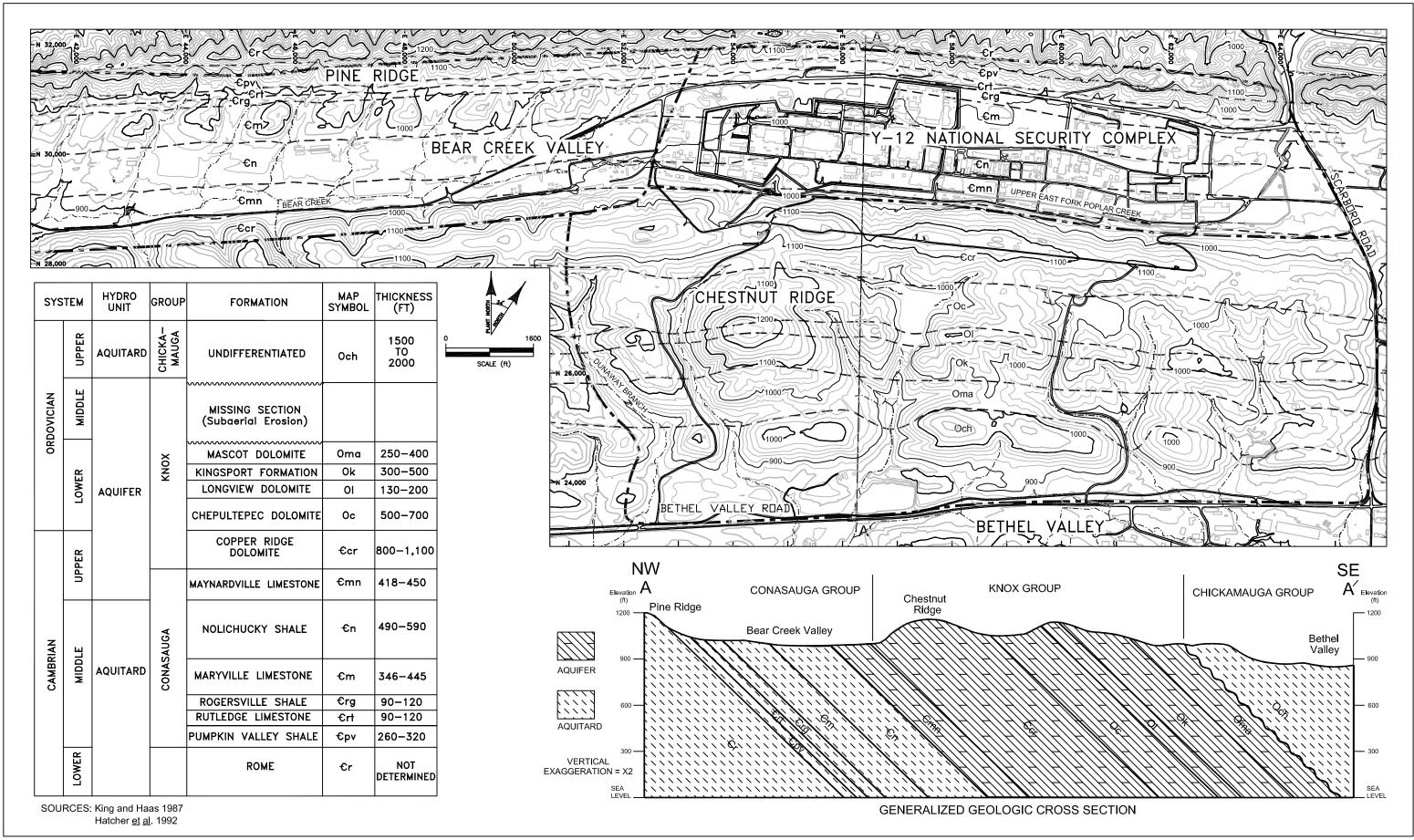
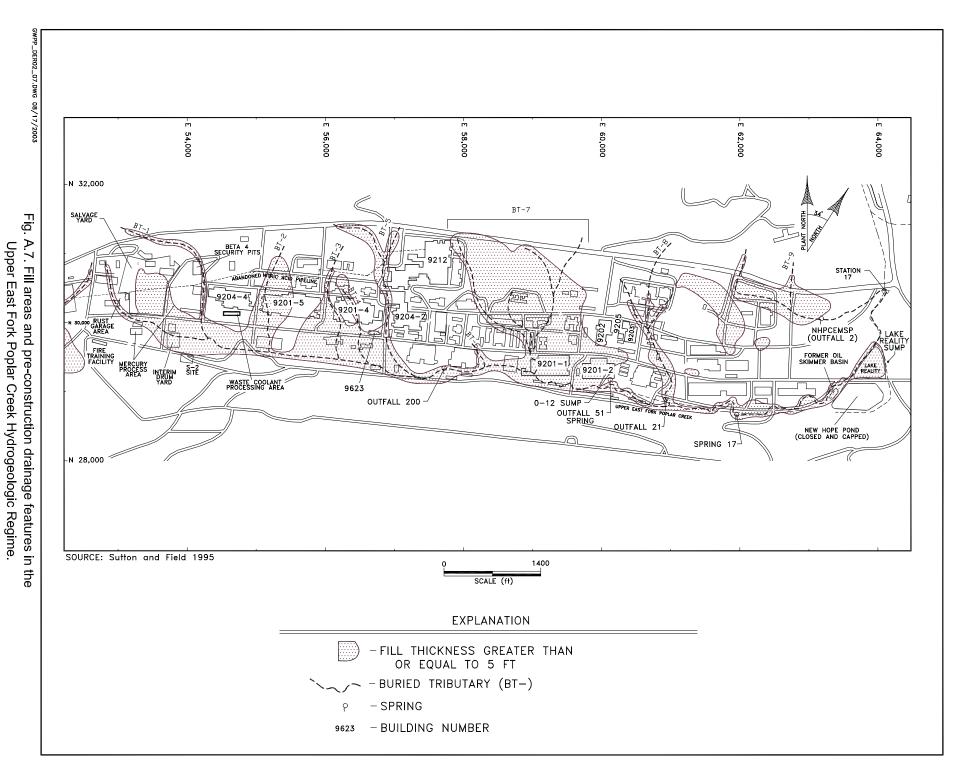
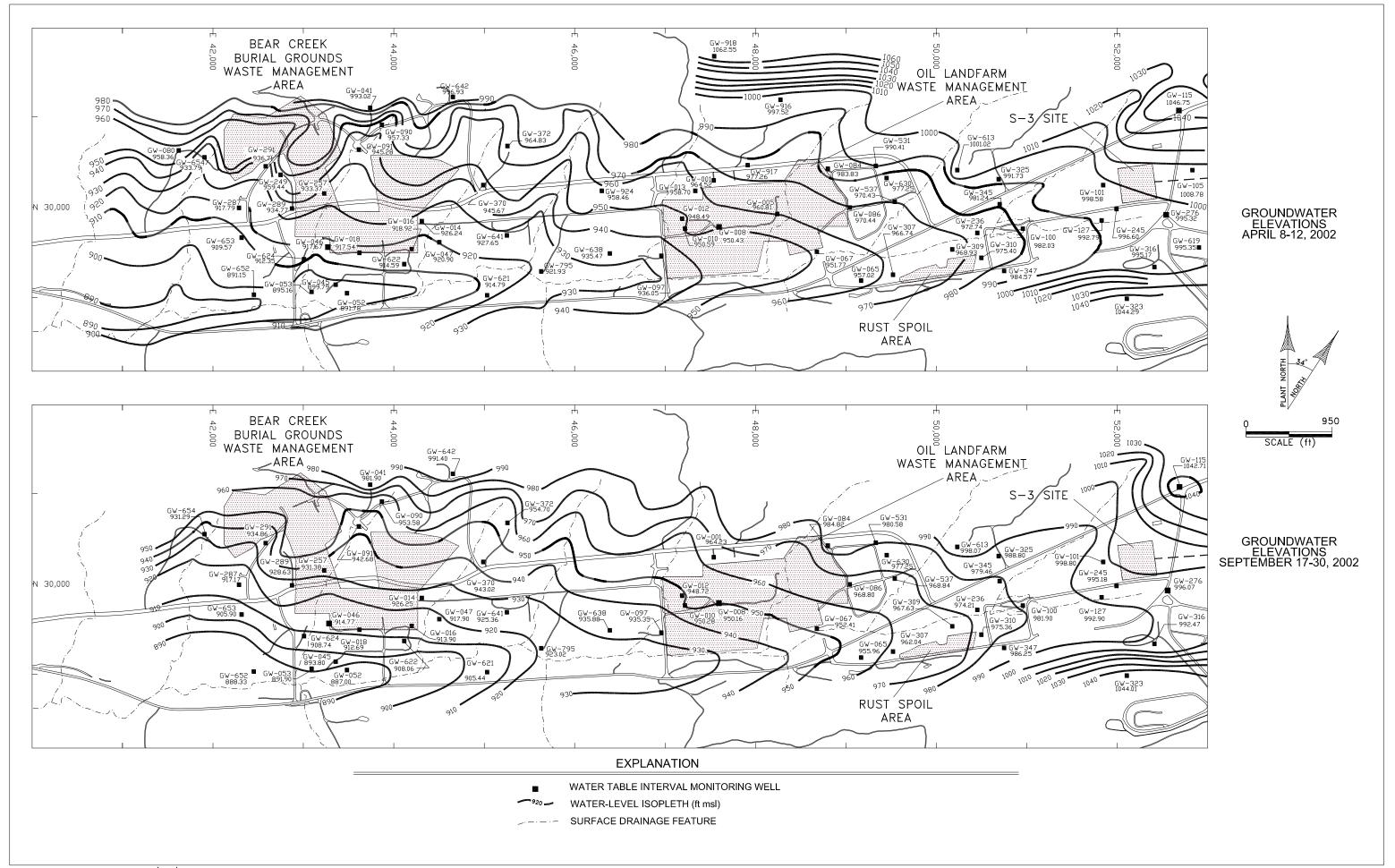


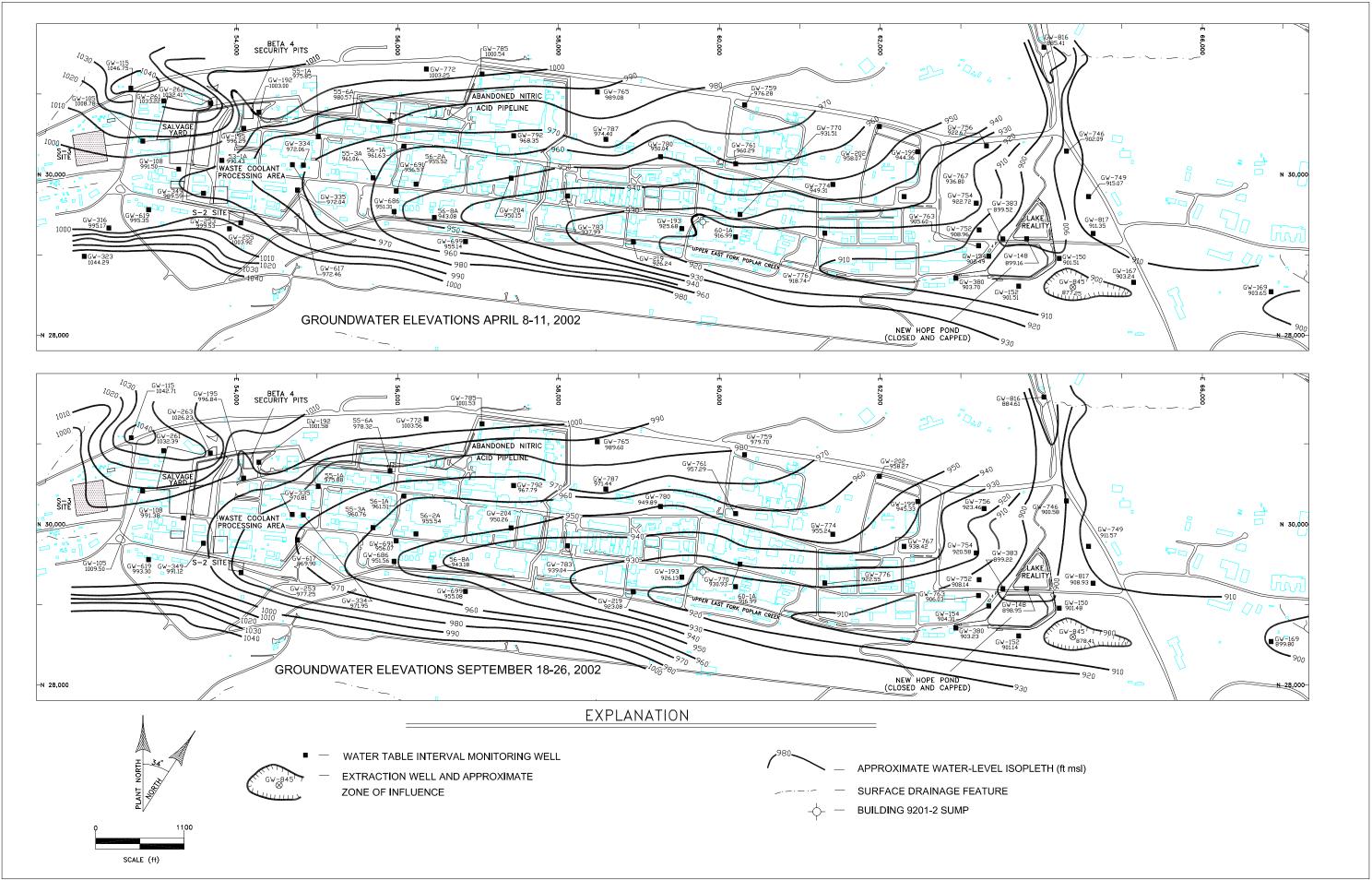
Fig. A.4. Westbay™ monitoring system sampling port depths in well GW-722.

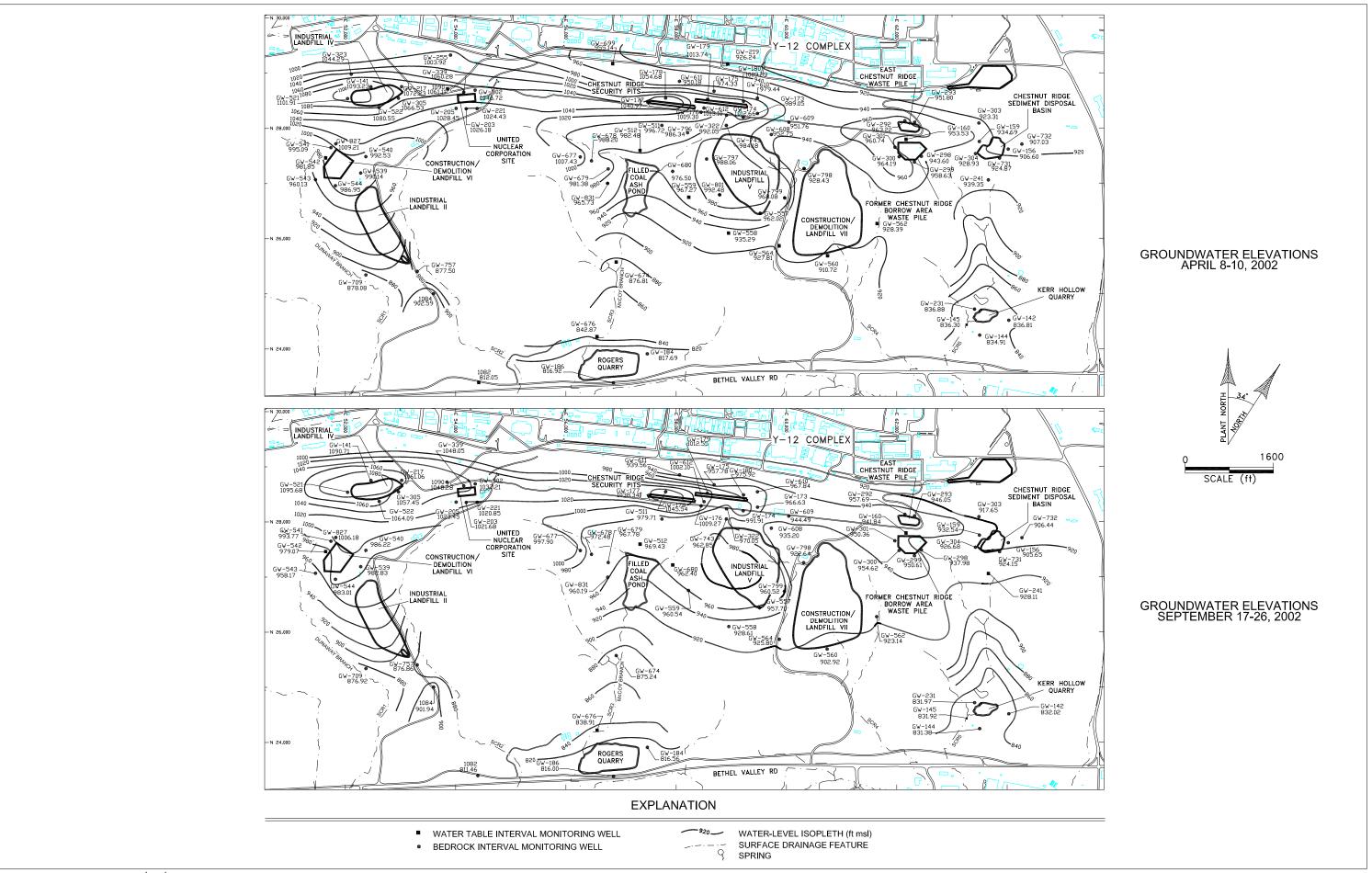


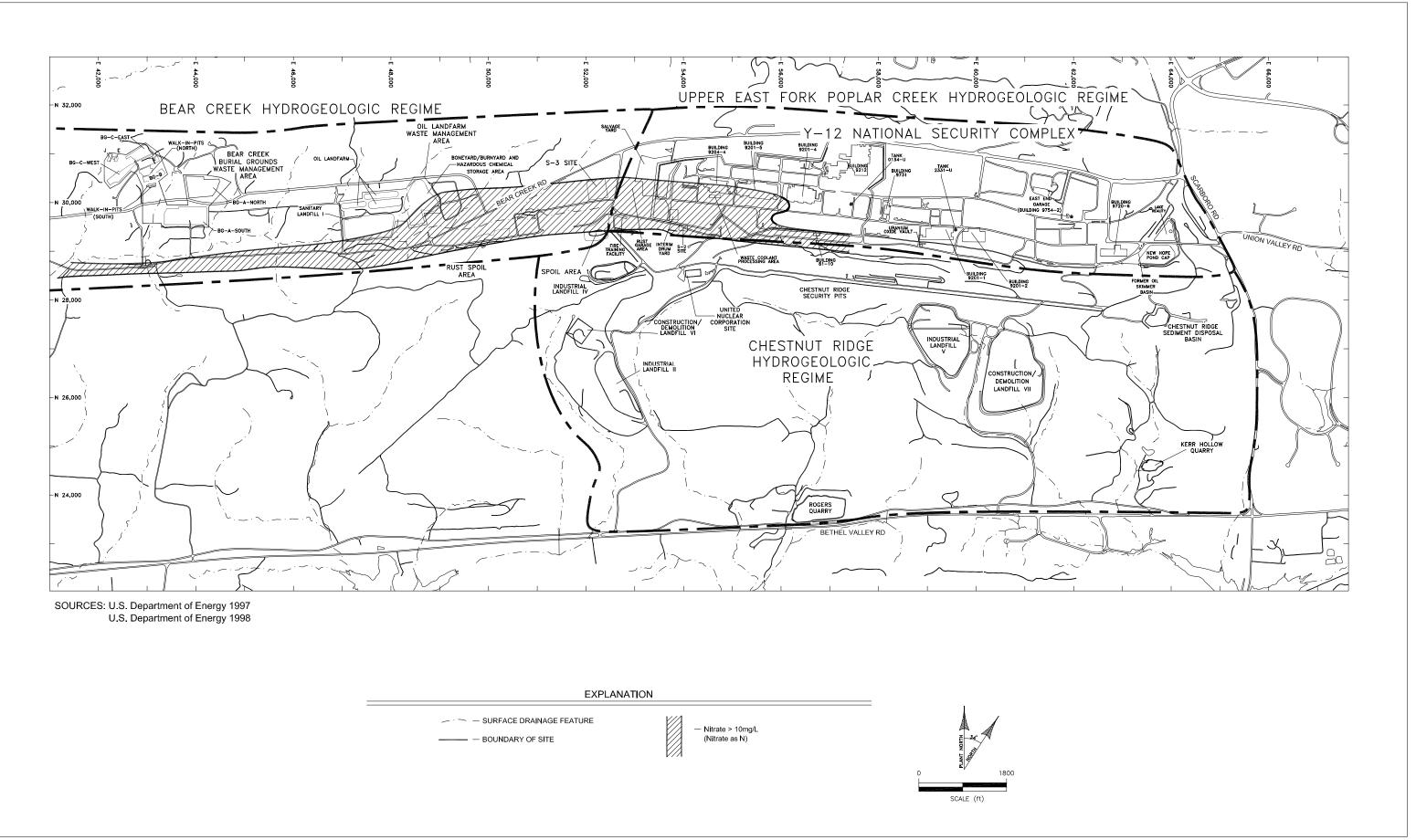


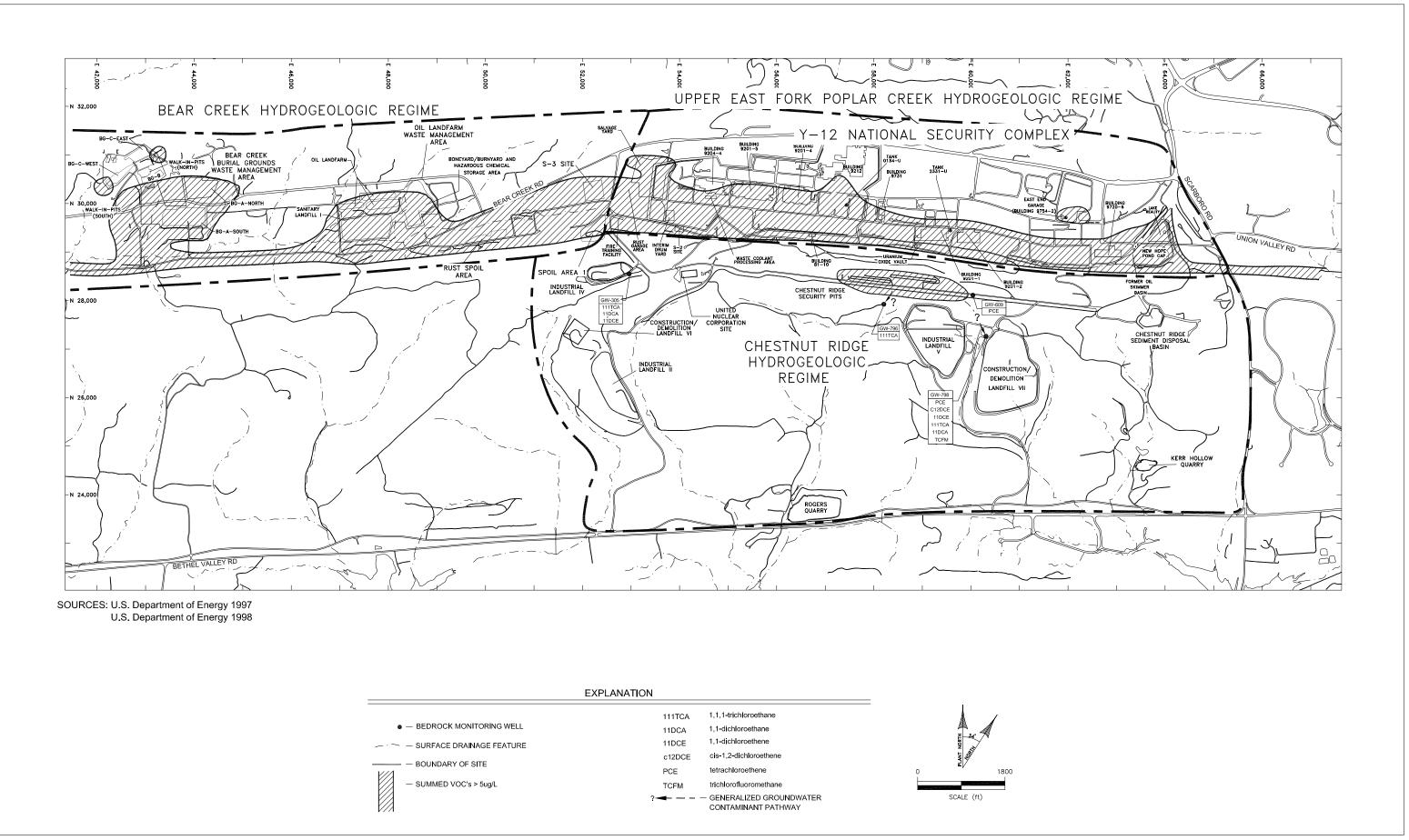


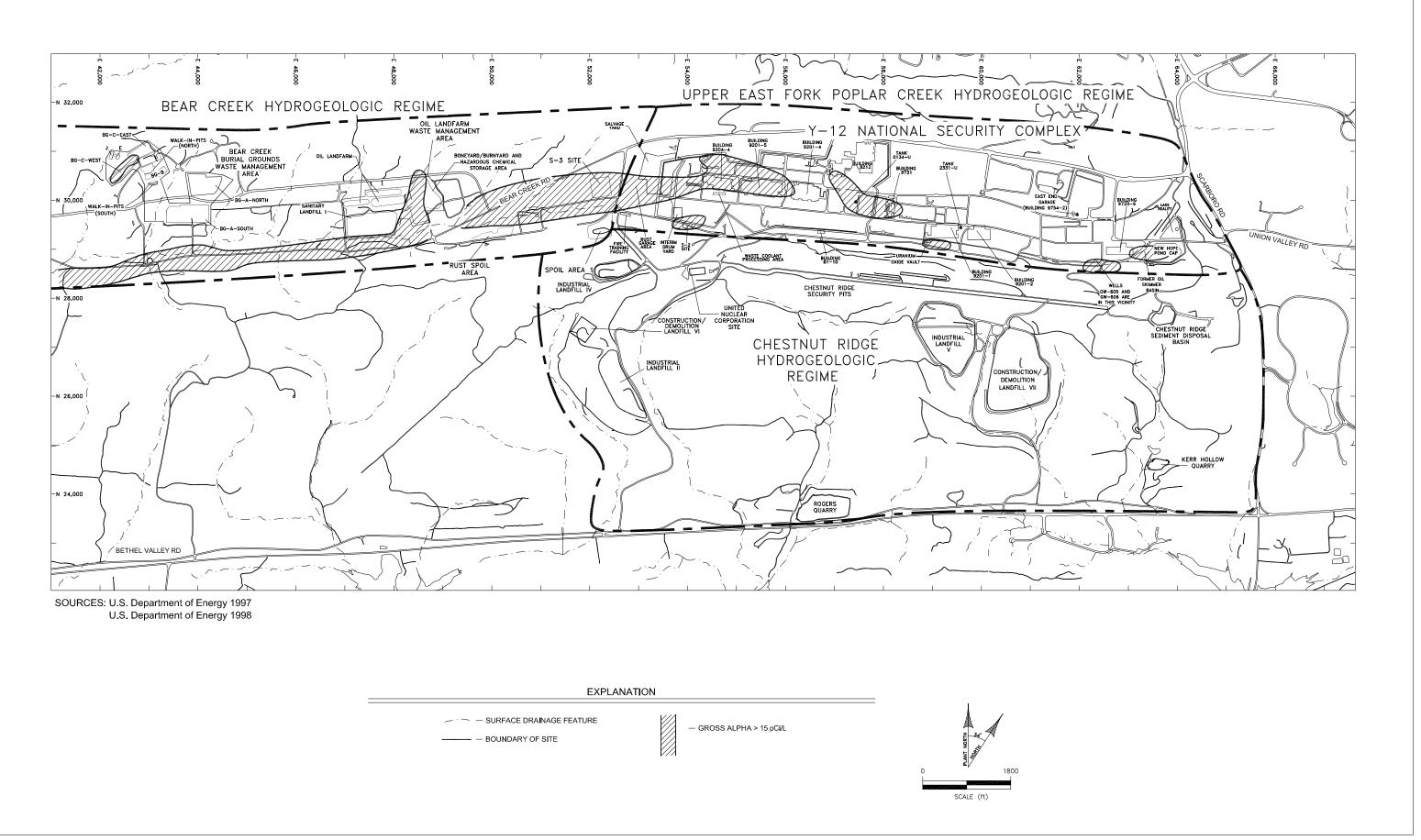


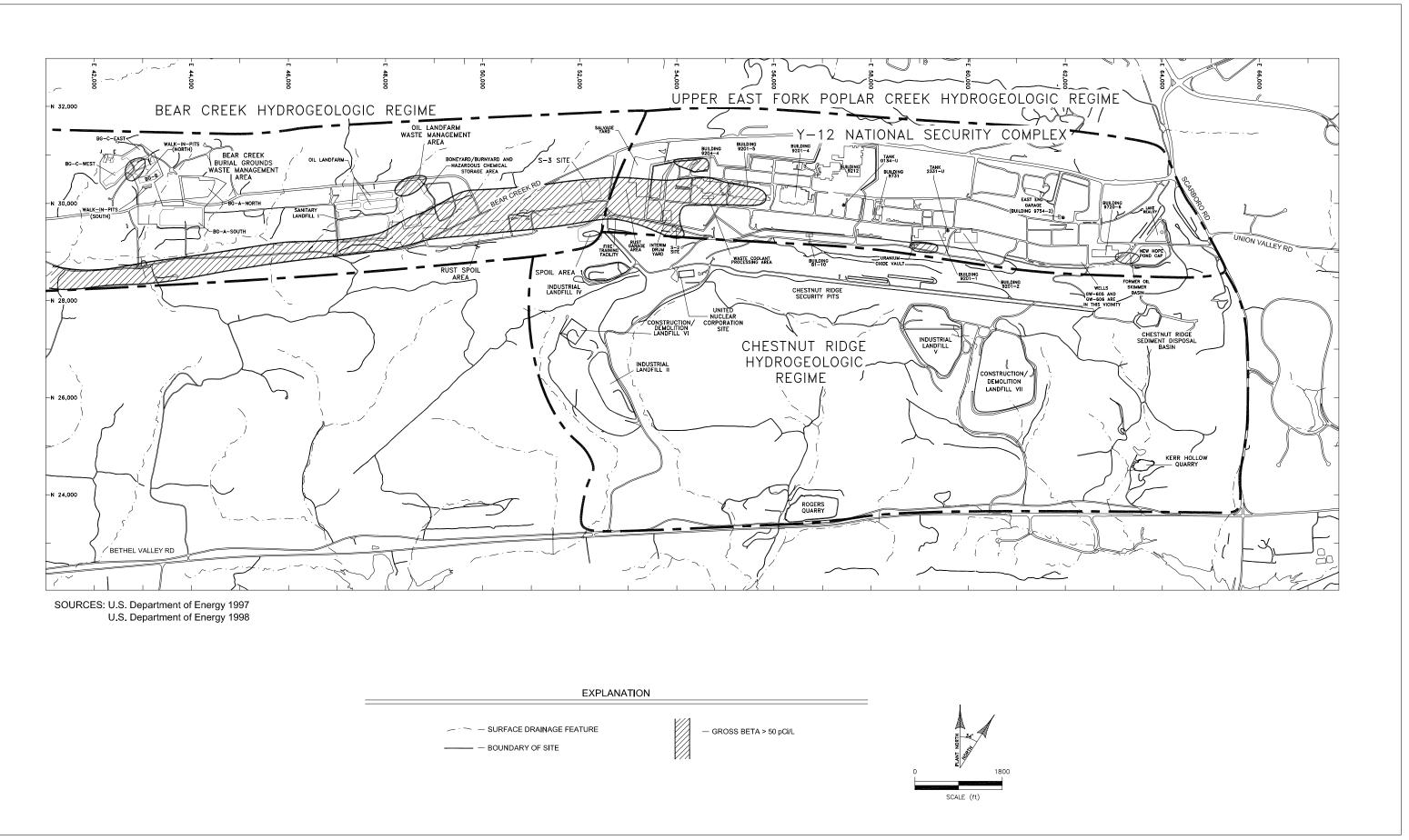


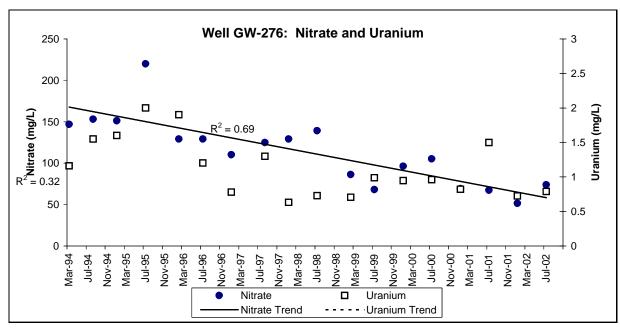


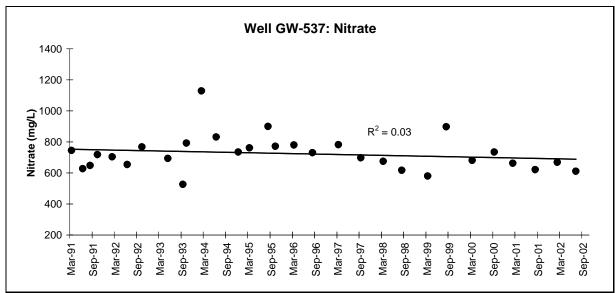












Note: Nitrate MCL = 10 mg/L; Uranium MCL = 0.03 mg/L

DER 02

Fig. A.15. Concentrations of inorganic contaminants in wells GW-276 and GW-537.

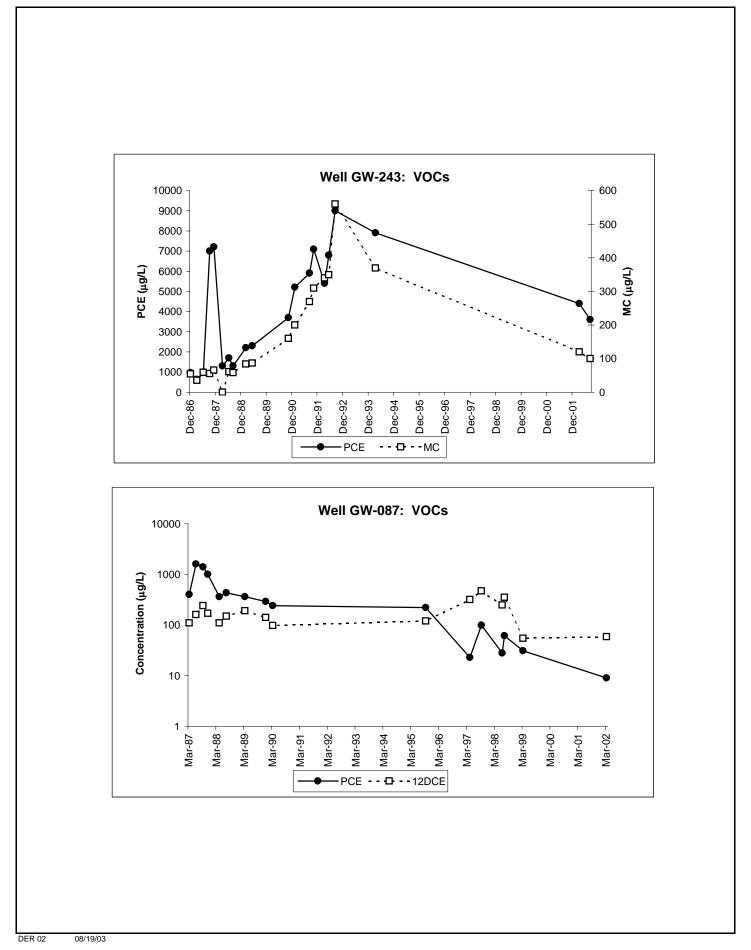
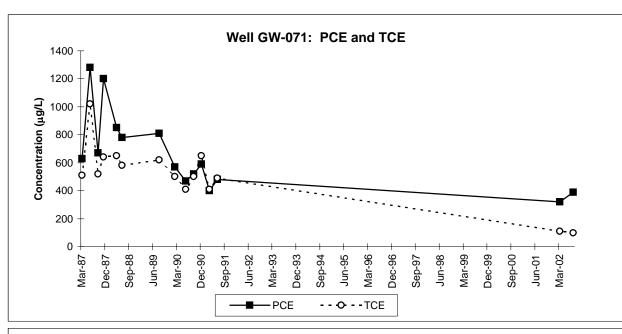


Fig. A.16. Concentrations of selected VOCs in wells GW-243 and GW-087.



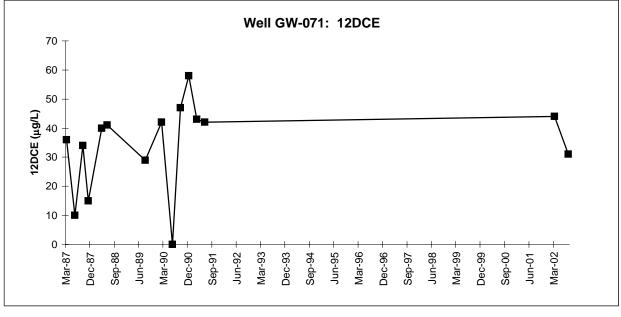
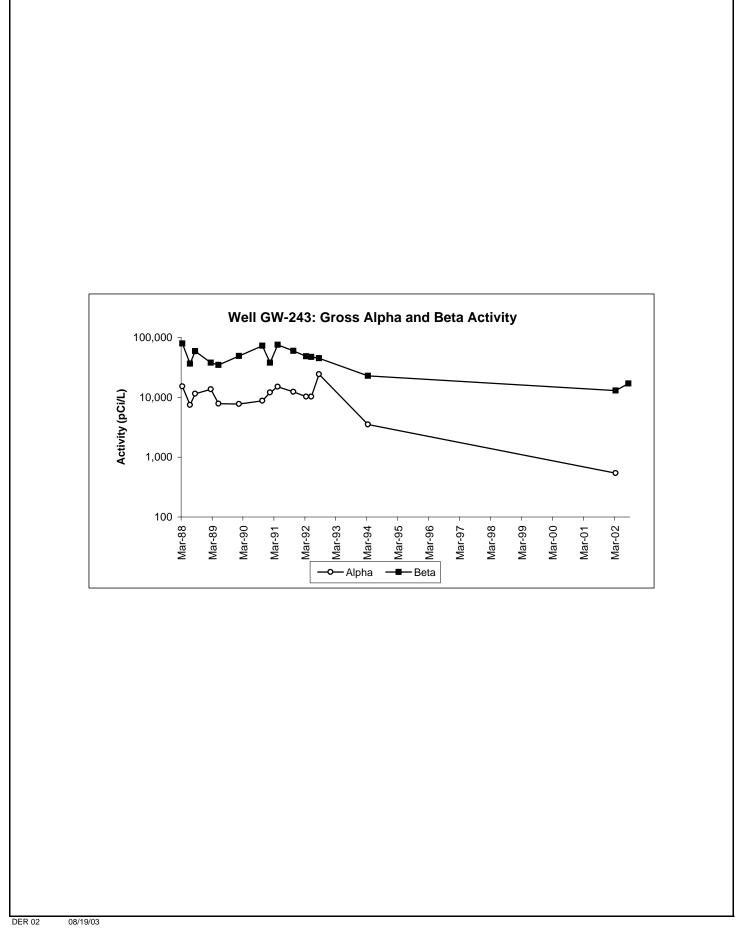


Fig. A.17. Concentrations of selected VOCs in well GW-071.



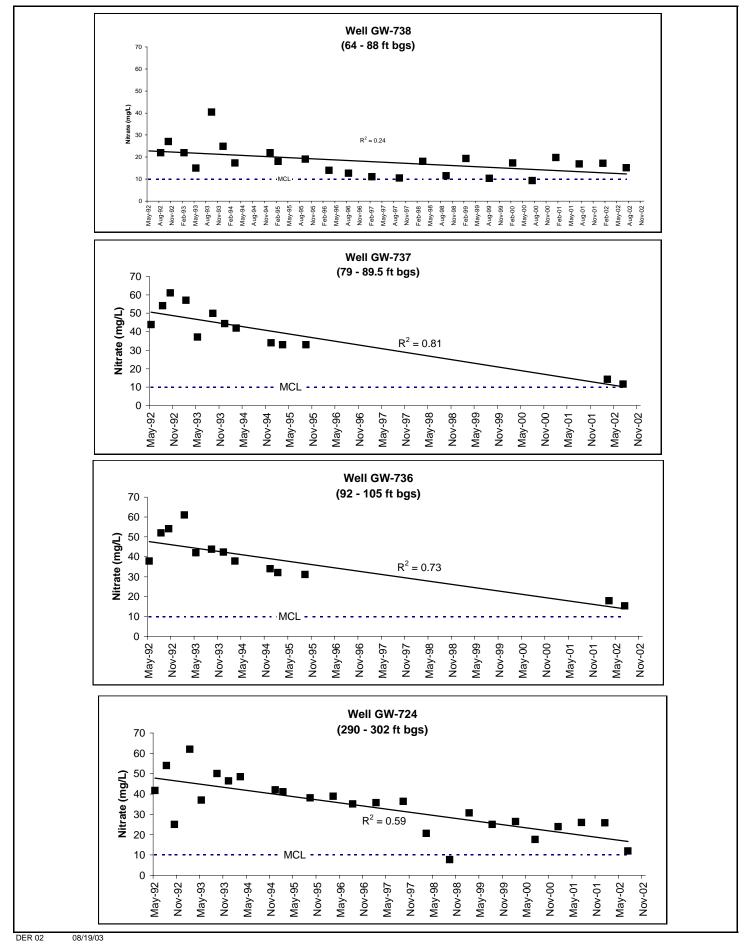
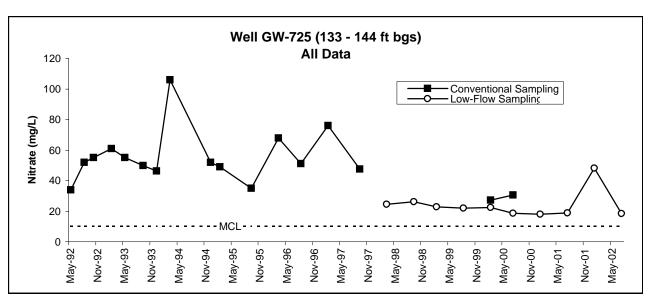
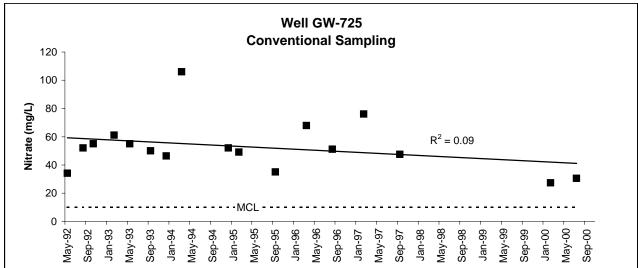


Fig. A.19. Nitrate concentrations in Exit Pathway Picket C wells.





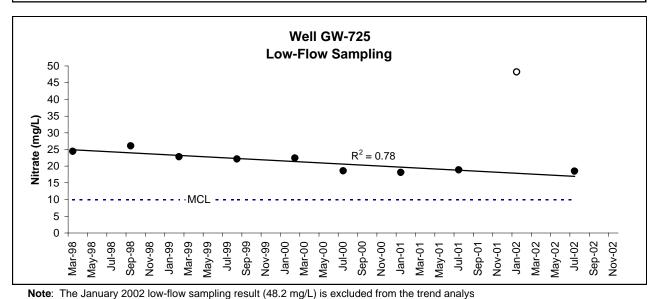
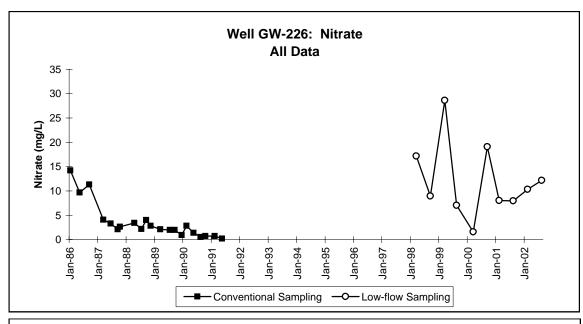
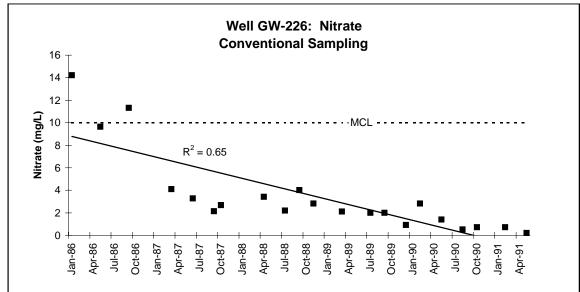


Fig. A.20. Nitrate concentrations in well GW-725.

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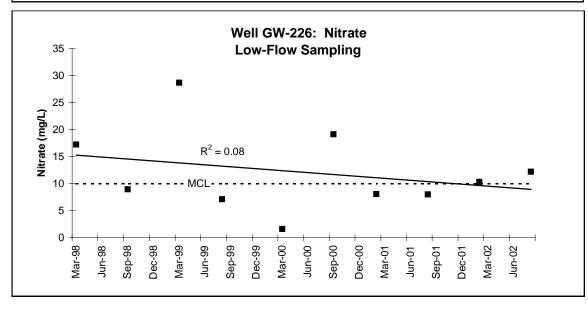
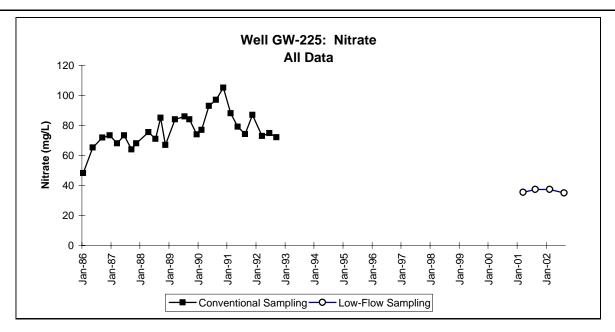
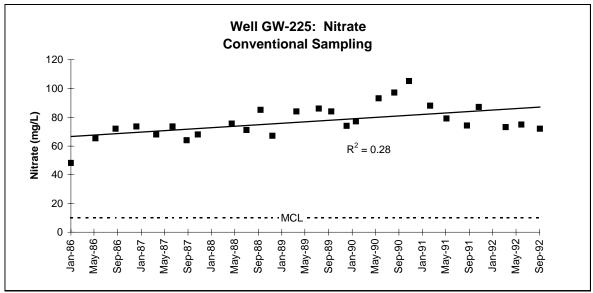


Fig. A.21. Nitrate concentrations in well GW-226.





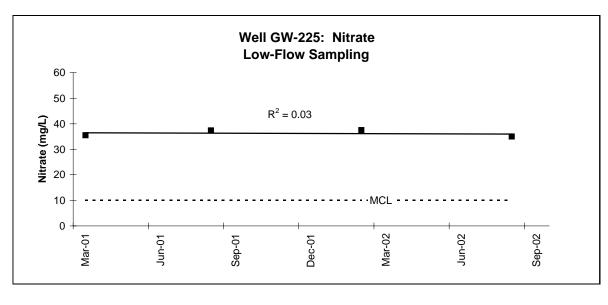
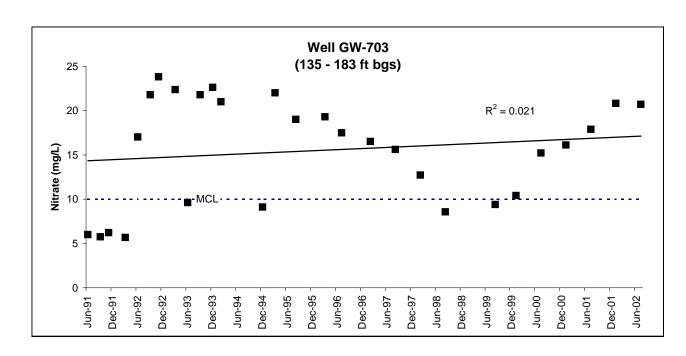


Fig. A.22. Nitrate concentrations in well GW-225.



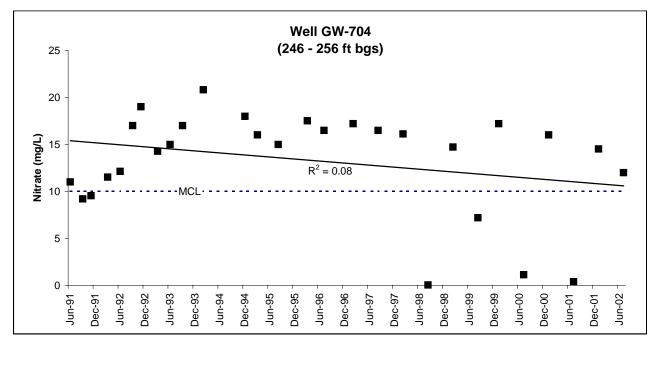
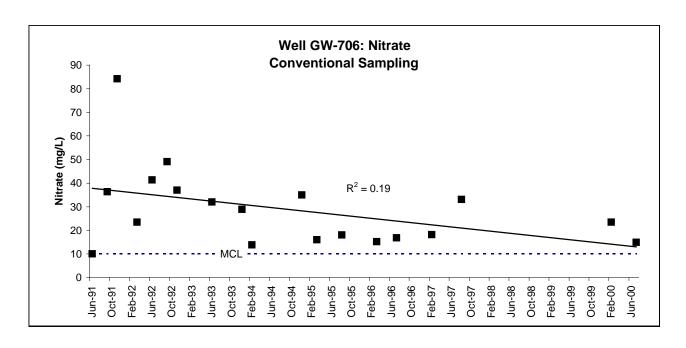
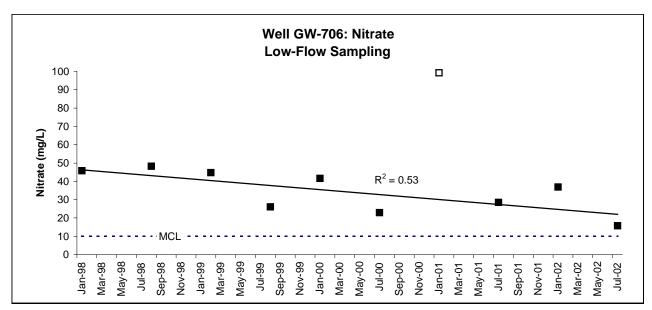


Fig. A.23. Nitrate concentrations in Exit Pathway Picket B wells.

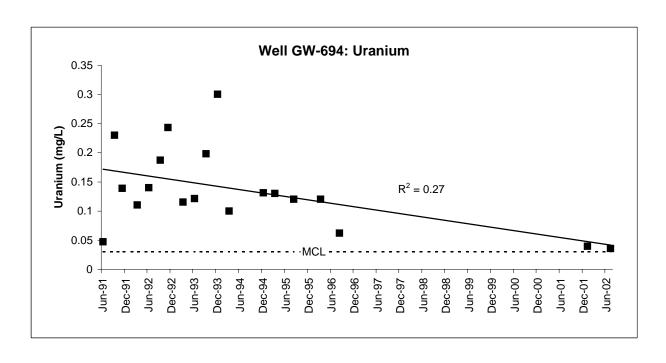




Note: The low-flow sampling trend excludes the January 2001 result (99.1 mg/L).

Fig. A.24. Nitrate concentrations in well GW-706.

DER 02



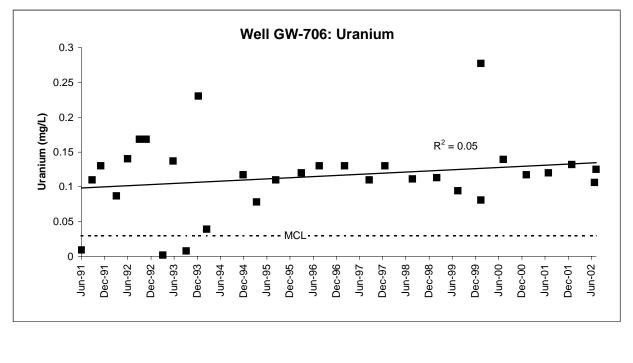


Fig. A.25. Uranium concentrations in wells GW-694 and GW-706.

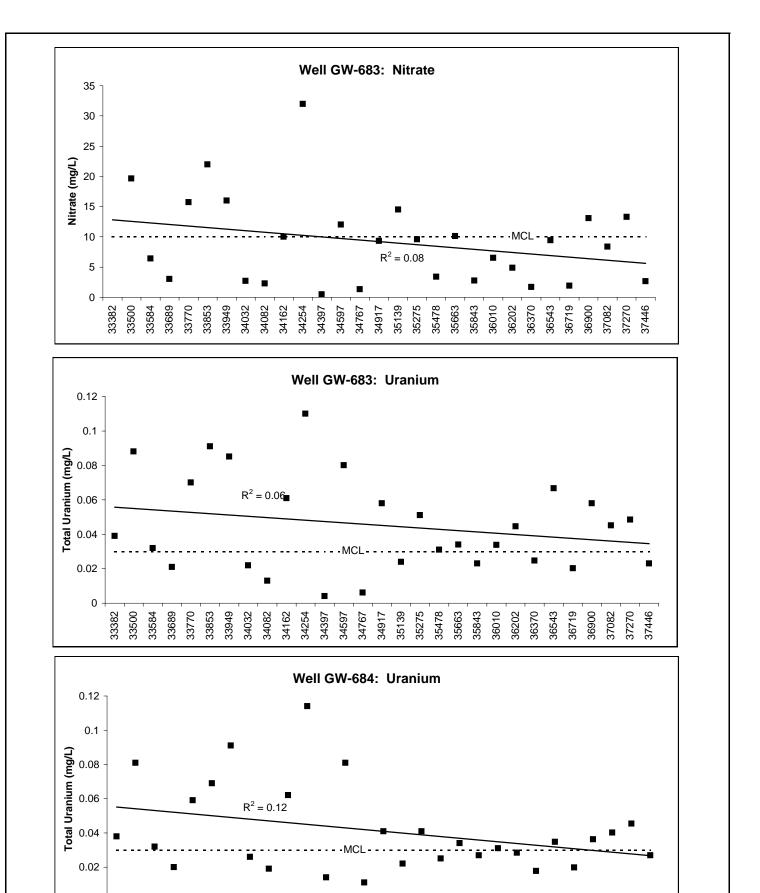


Fig. A.26. Nitrate and uranium concentrations in Exit Pathway Picket A wells.

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DER 02

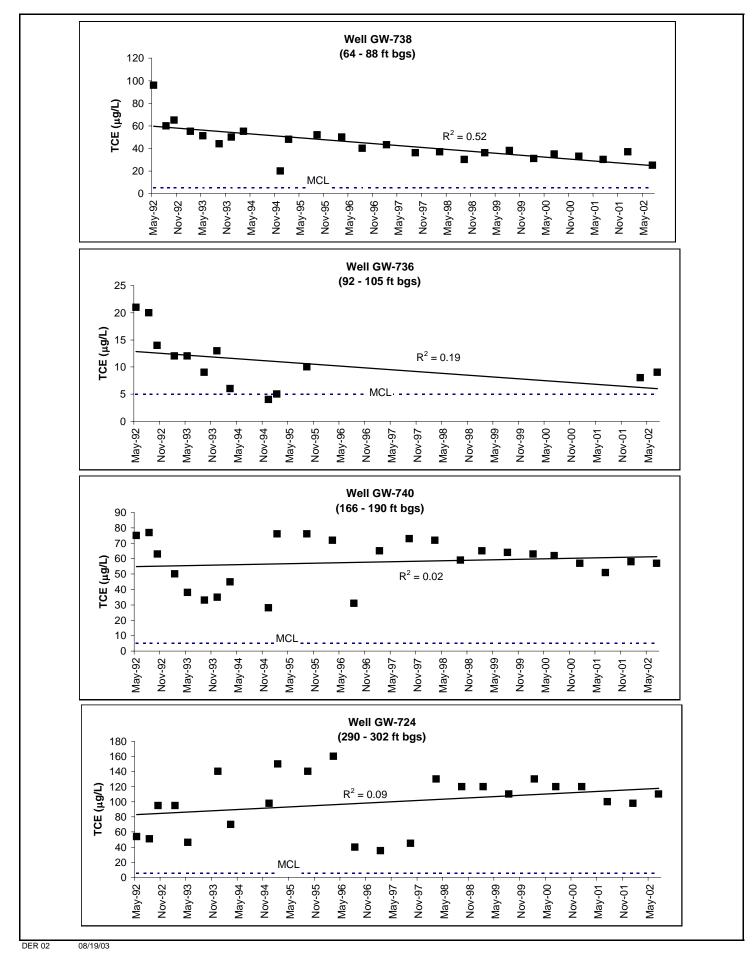
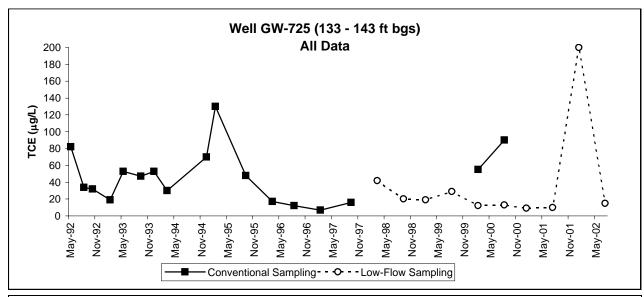
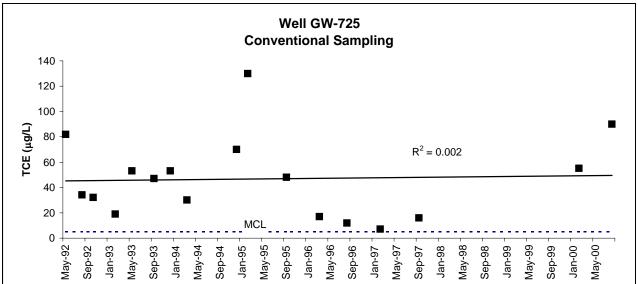
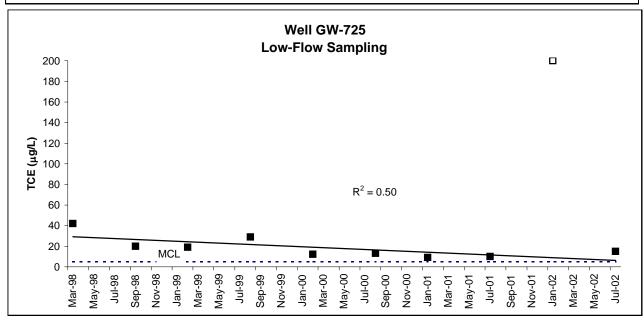
 

Fig. A.27. Concentrations of TCE in Exit Pathway Picket C wells.





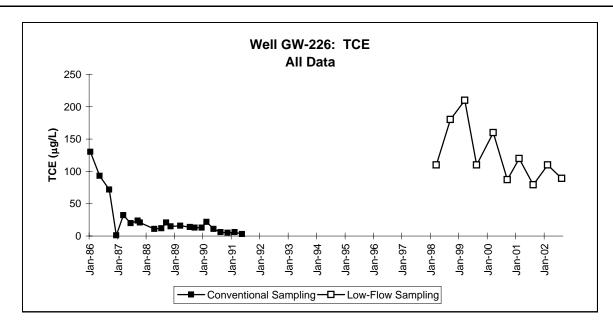


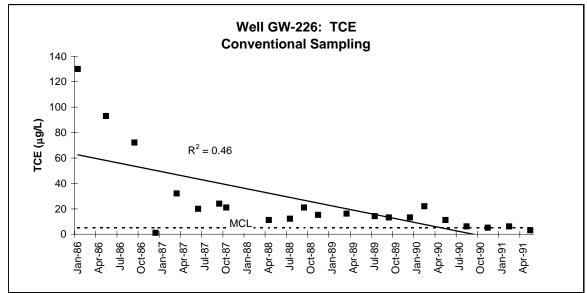
Note: The January 2002 low-flow sampling result (20Q g/L) is excluded from the trend analysis.

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Fig. A.28. Concentrations of TCE in well GW-725.





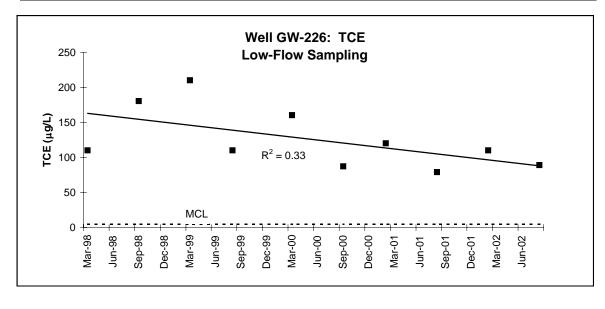
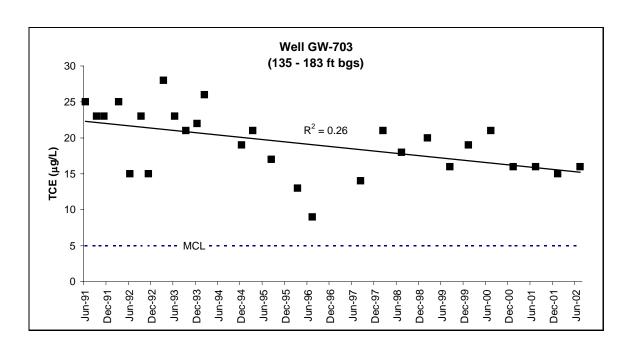


Fig. A.29. Concentrations of TCE in well GW-226.



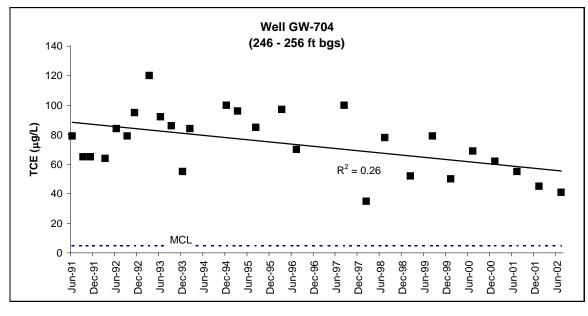
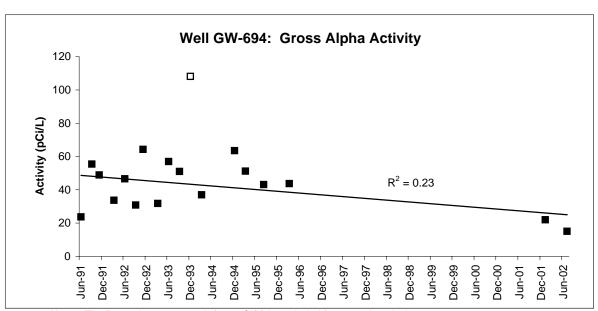


Fig. A.30. Concentrations of TCE in wells GW-703 and GW-704.



Note: The December 1993 result (108 pCi/L) is excluded from trend analysis.

DER 02 08/19/03

Fig. A.31. Gross alpha activity in well GW-694.

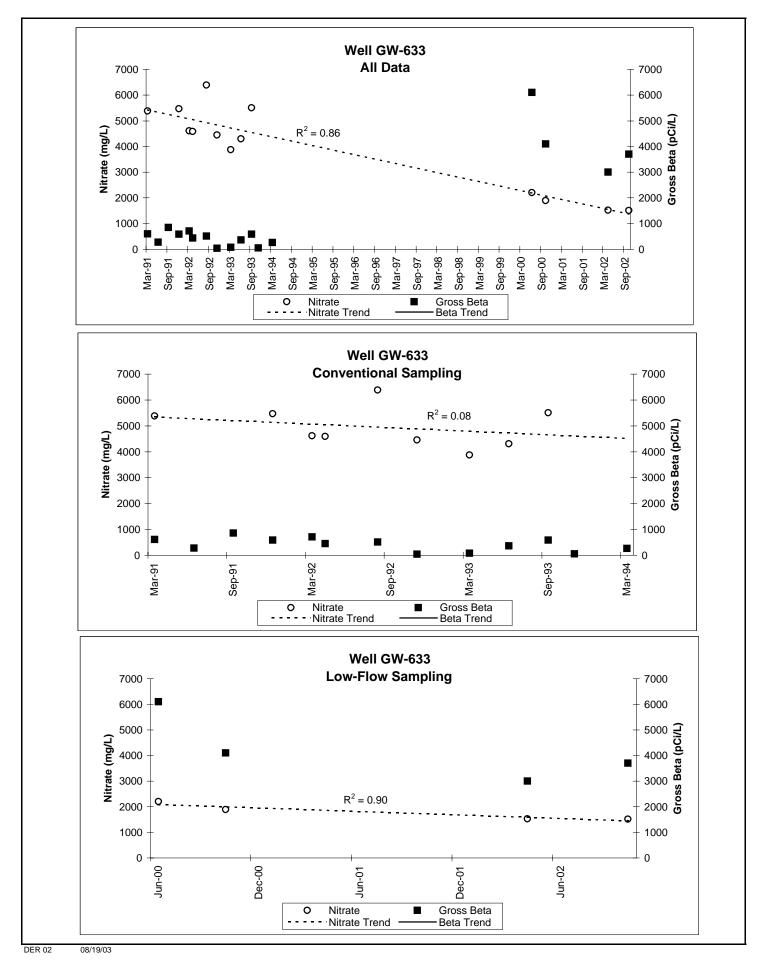


Fig. A.32. Nitrate concentrations and gross beta activity in well GW-633.

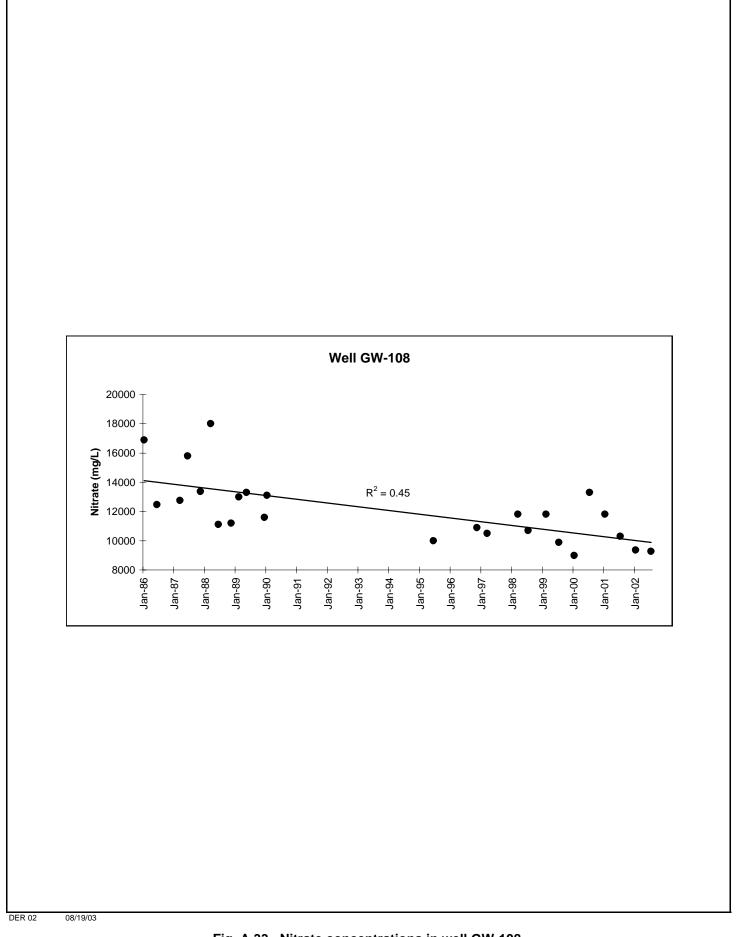
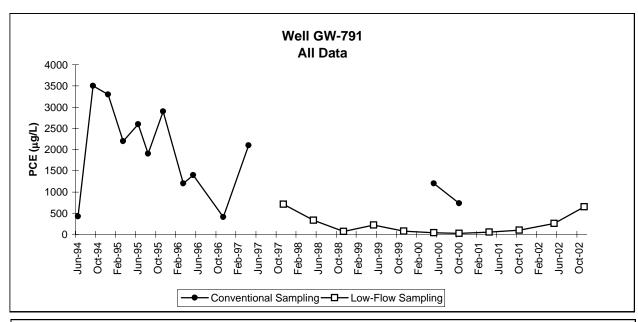
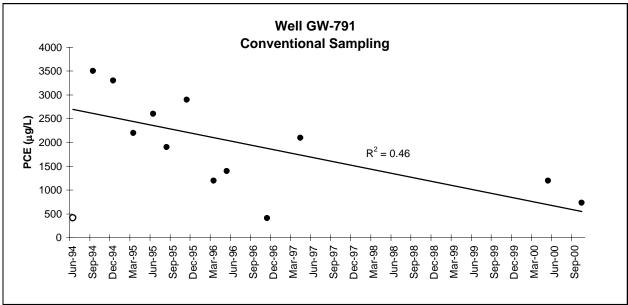


Fig. A.33. Nitrate concentrations in well GW-108.





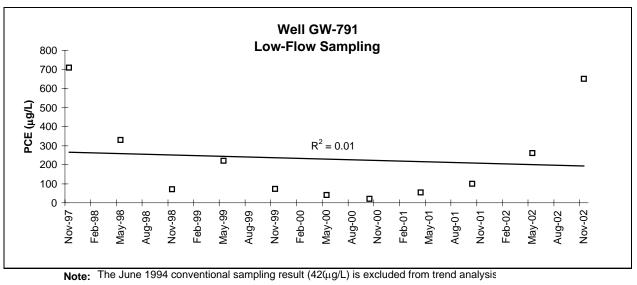
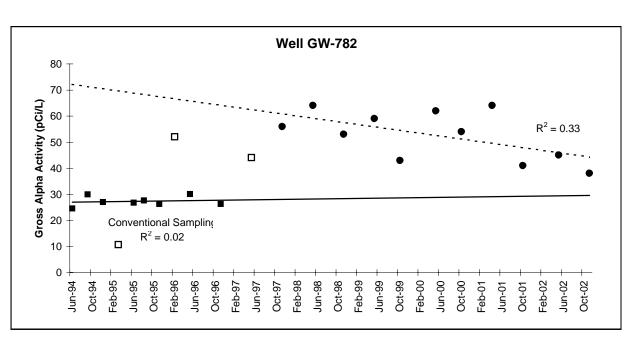


Fig. A.34. Concentrations of PCE in well GW-791.

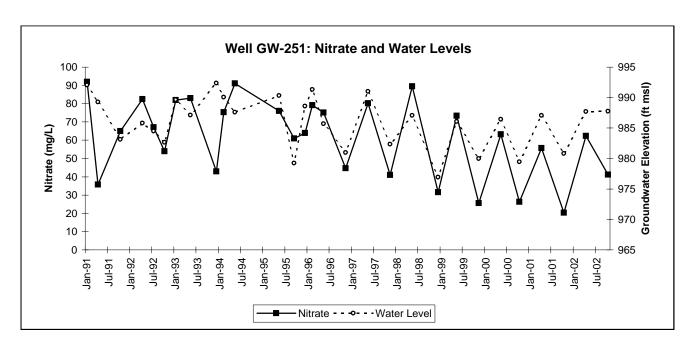
DER 02



Note: Results for conventional samples collected in Mar 1995 (10.7 pCi/L), Feb 1996 (52 pCi/L), and May 1997 (44 pCi/L) are excluded from the trend analysis because these atypical results skew the conventional sampling trend upward.

DER 02 08/19/03

Fig. A.35. Gross alpha activity in well GW-782.



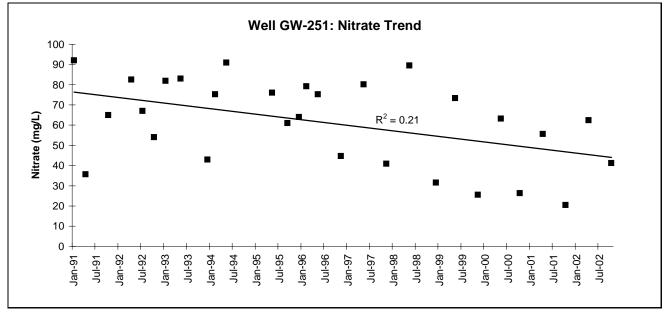
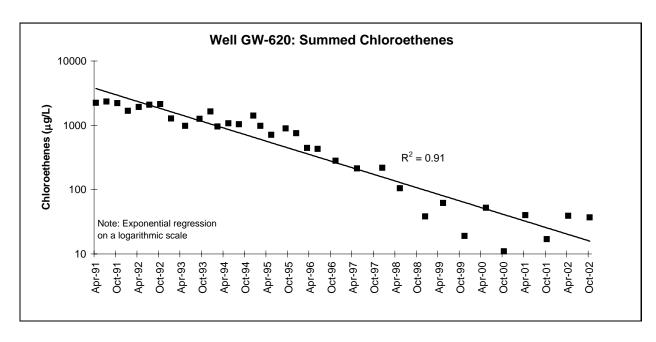


Fig. A.36. Nitrate concentrations in well GW-251.



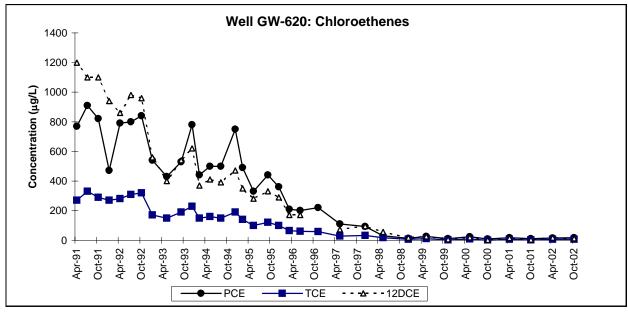
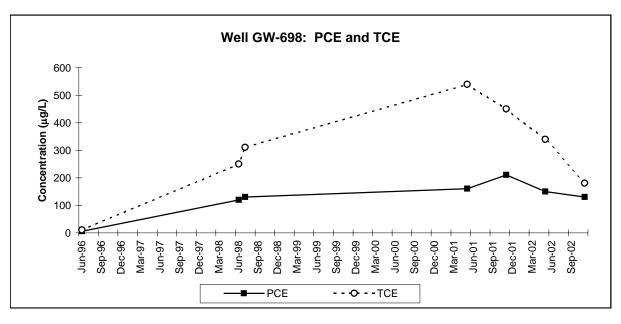


Fig. A.37. Concentrations of VOCs in well GW-620.



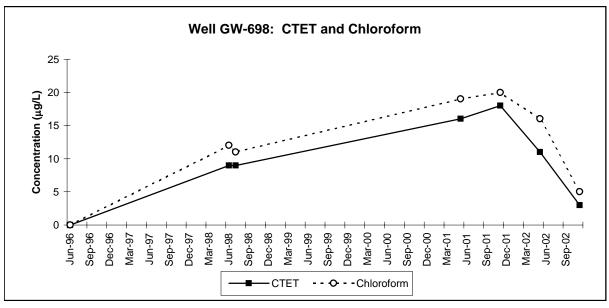
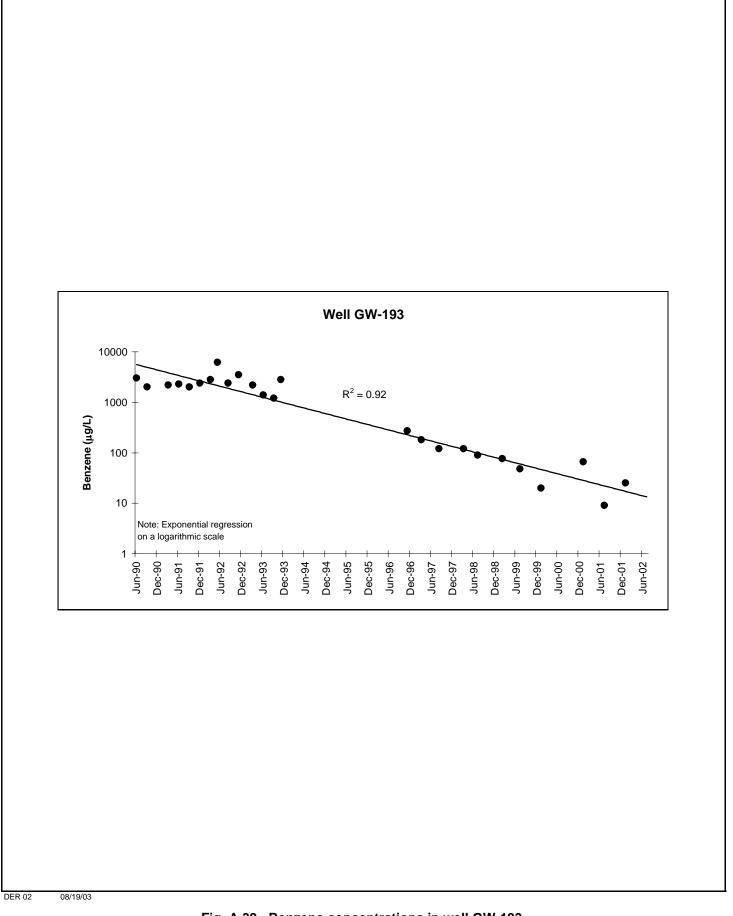
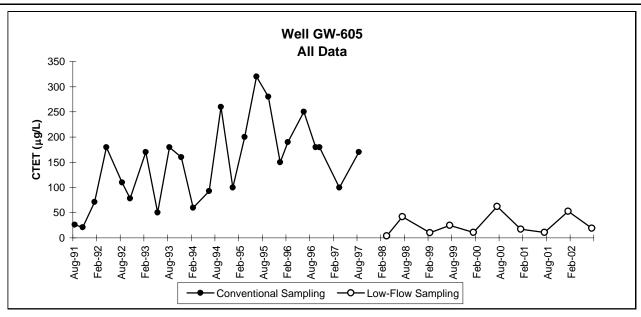
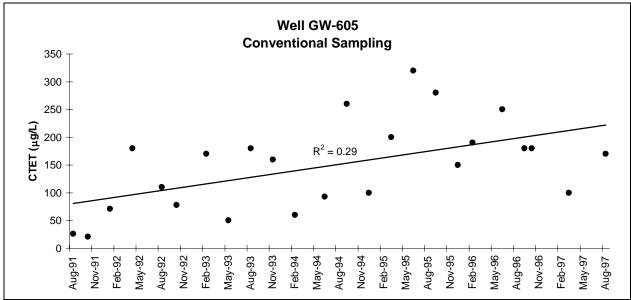


Fig. A.38. Concentrations of VOCs in well GW-698.







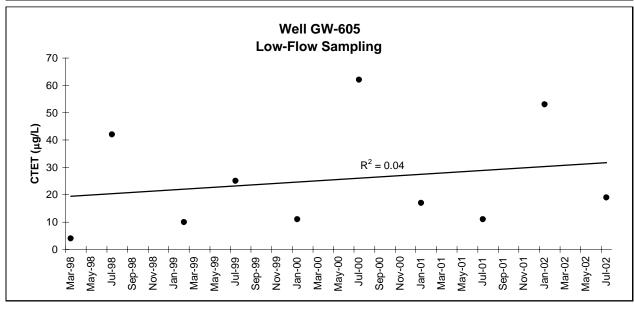
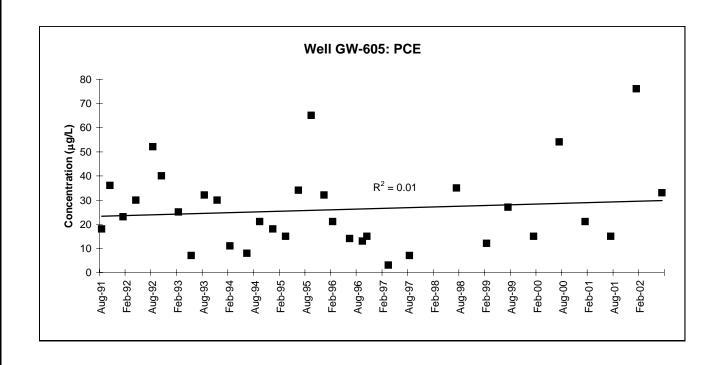


Fig. A.40. Concentrations of CTET in well GW-605.



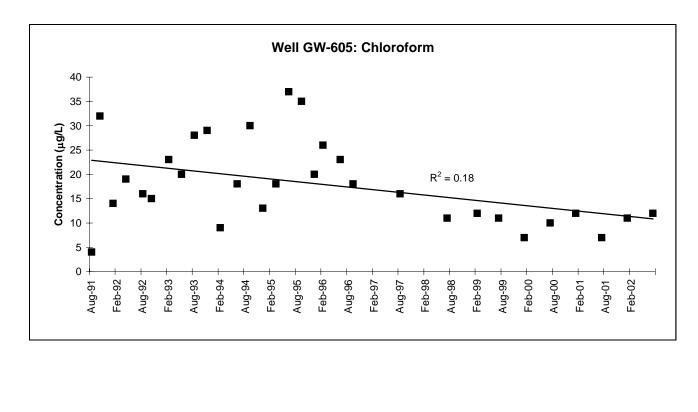


Fig. A.41. Concentrations of PCE and chloroform in well GW-605.

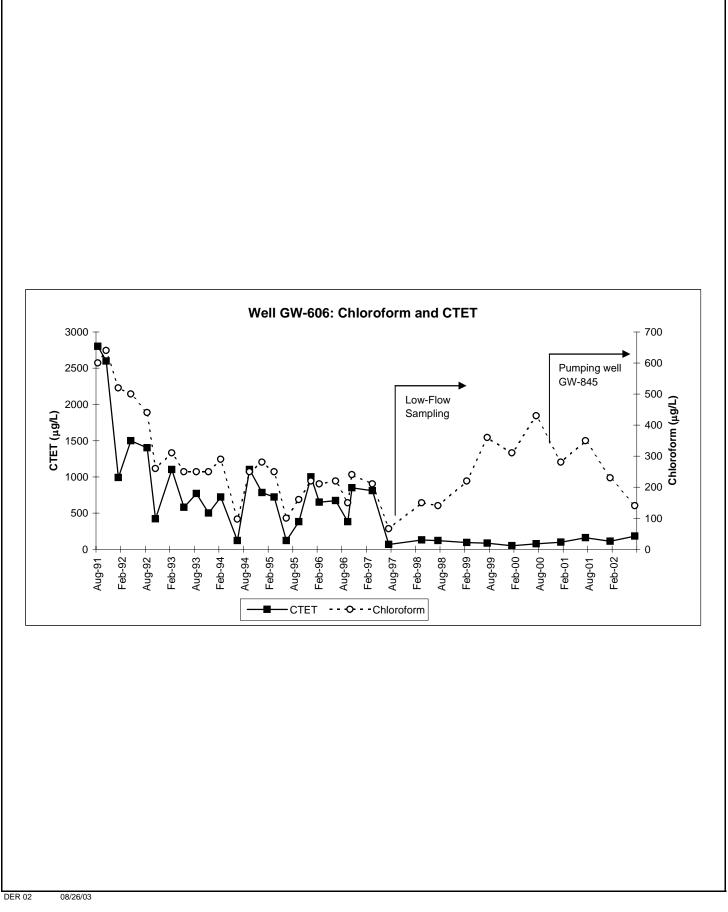
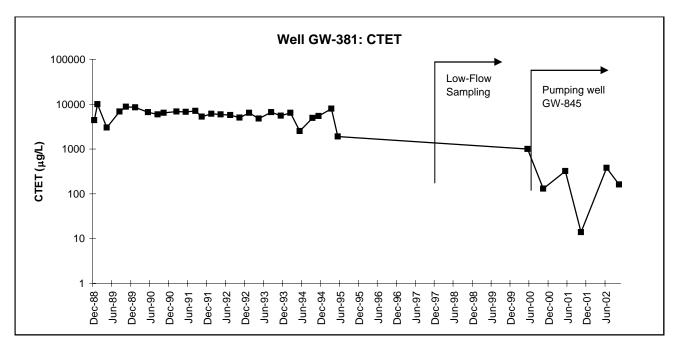


Fig. A.42. Concentrations of CTET and chloroform in well GW-606.



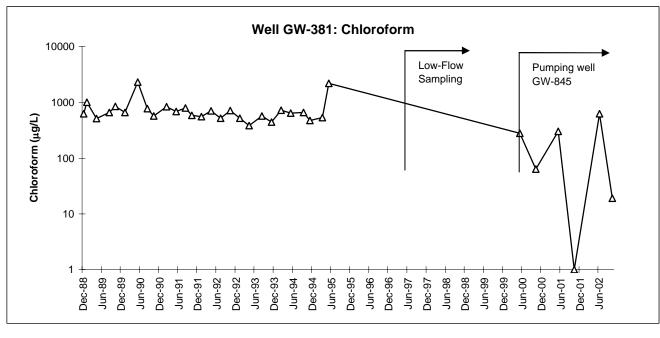
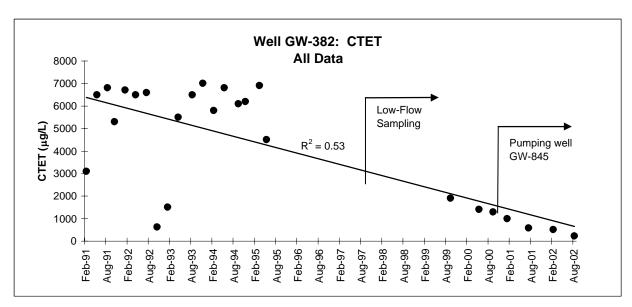
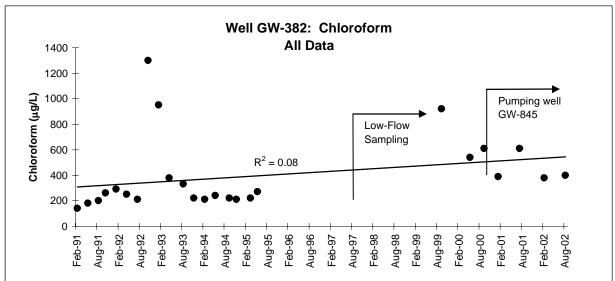


Fig. A.43. Concentrations of CTET and chloroform in well GW-381.





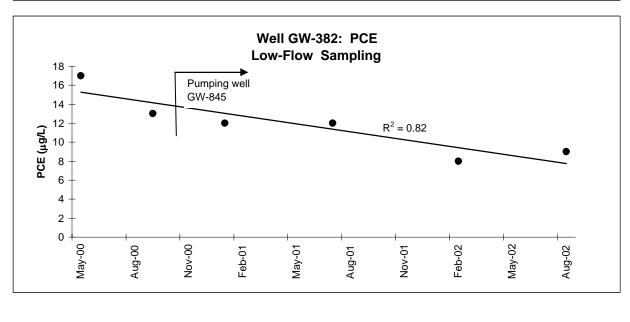
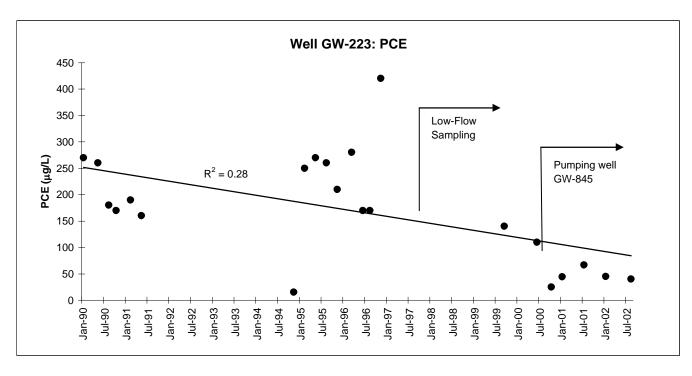


Fig. A.44. Concentrations of VOCs in well GW-382.



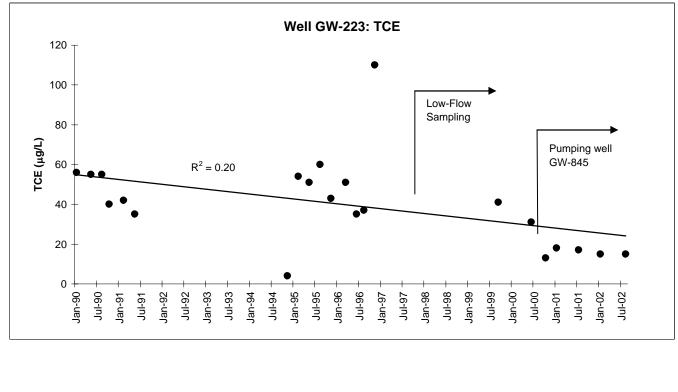
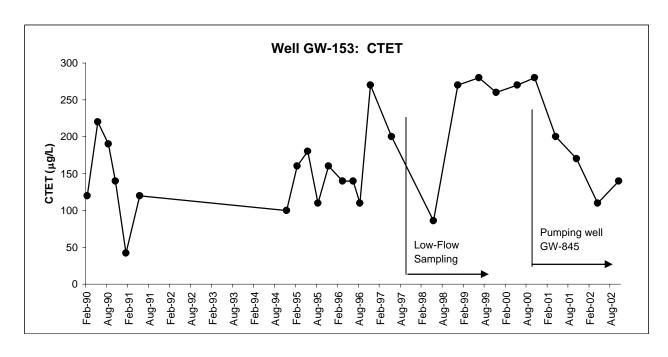


Fig. A.45. Concentrations of PCE and TCE in well GW-223.



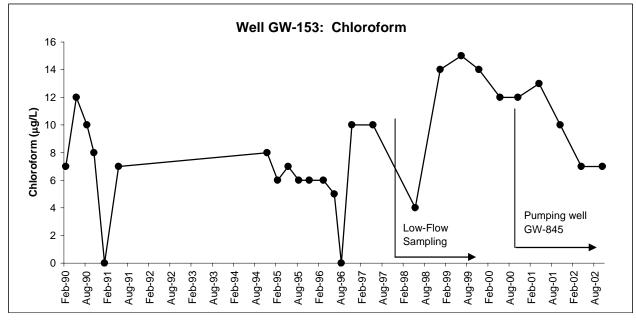
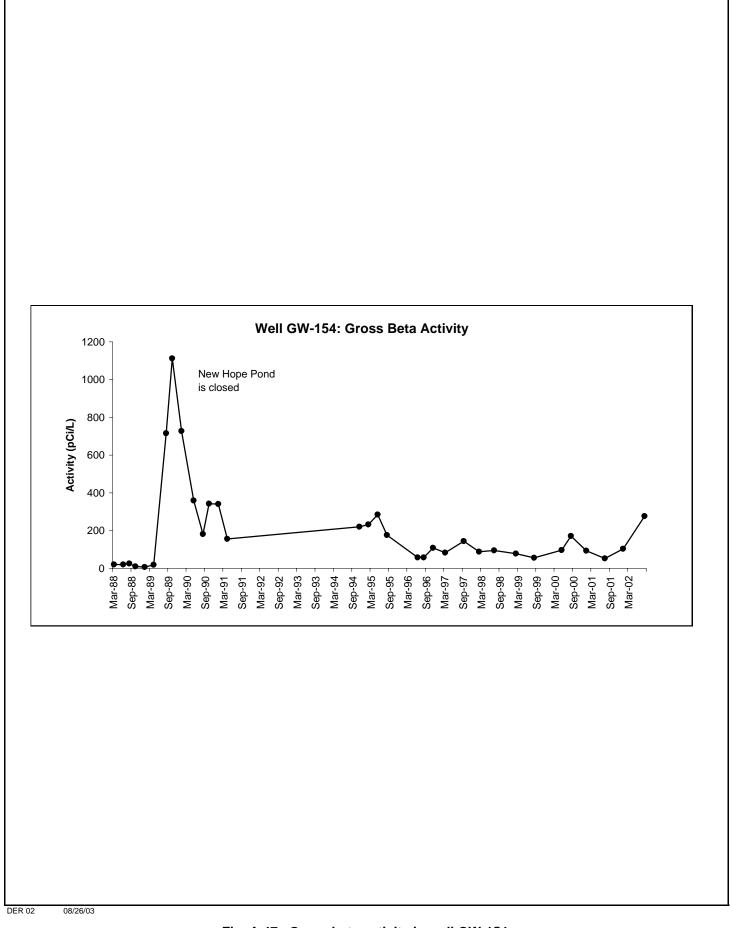
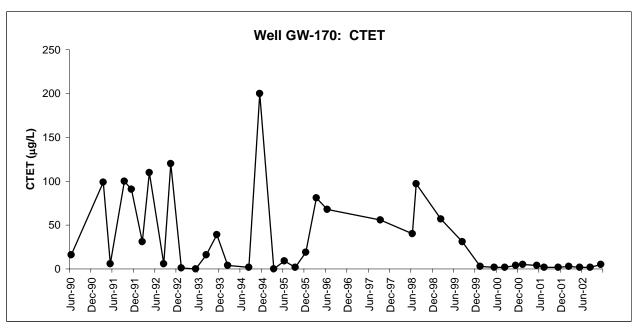


Fig. A.46. Concentrations of CTET and chloroform in well GW-153.





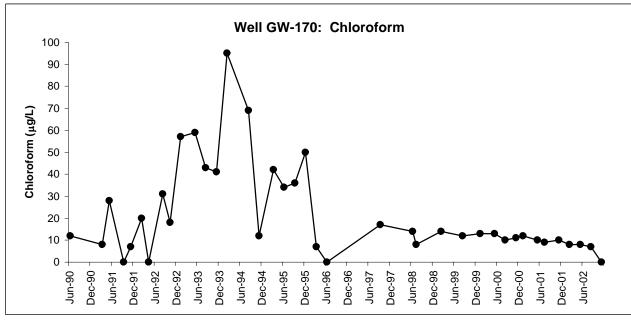
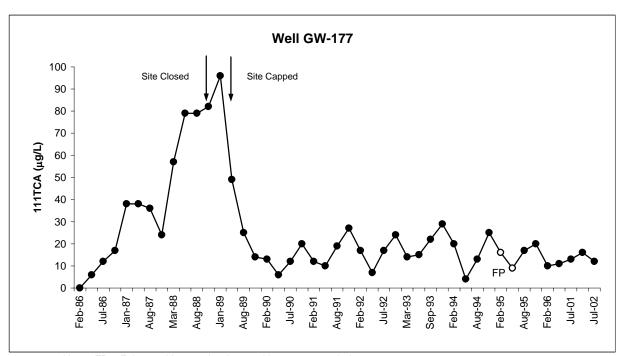


Fig. A.48. Concentrations of CTET and chloroform in well GW-170.



Note: FP = False positive results shown with an open symbol.

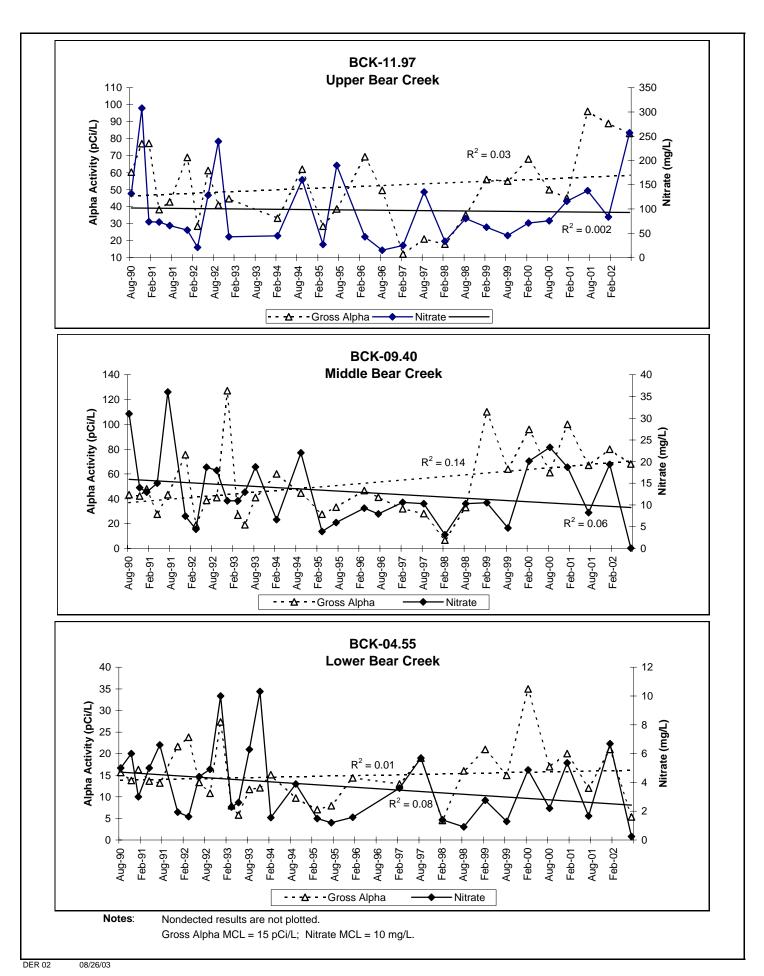
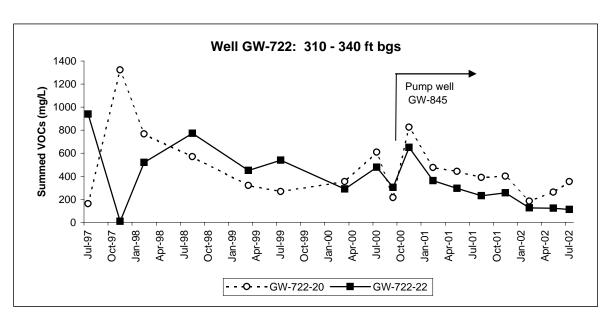


Fig. A.50. Contaminant concentrations in Bear Creek.



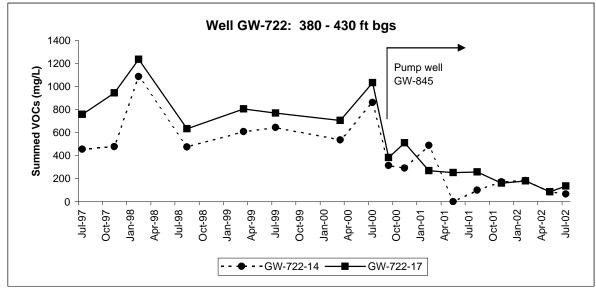


Fig. A.51. Concentrations of VOCs in well GW-722 sampling ports 14, 17, 20, and 22.

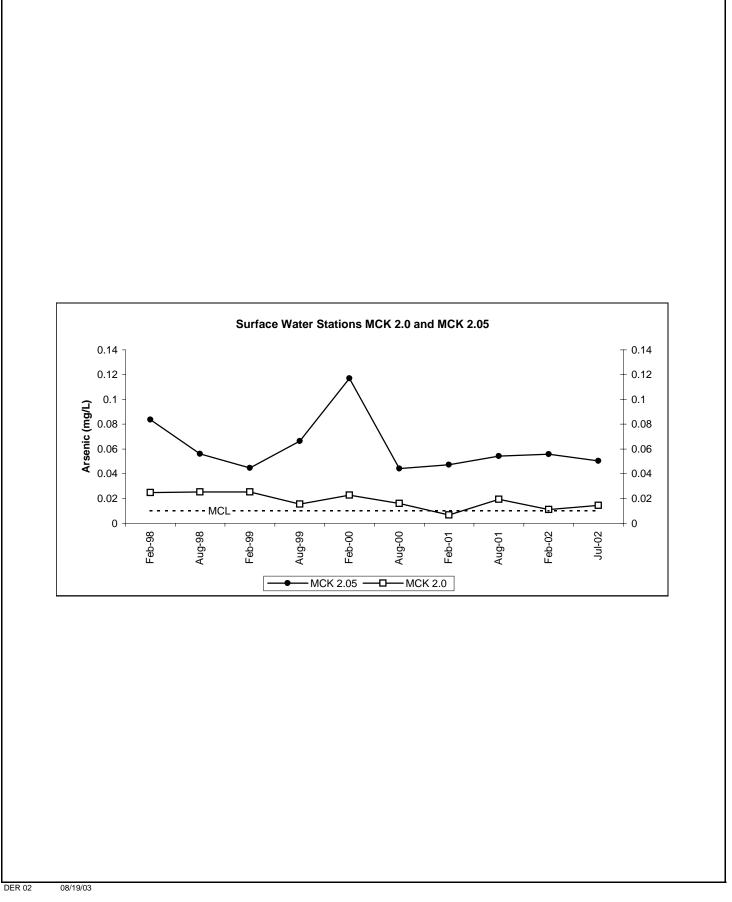
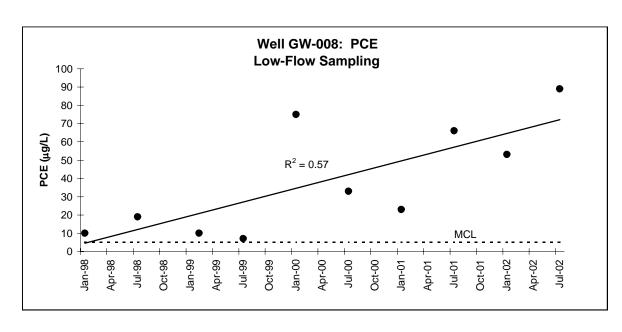


Fig. A.52. Arsenic concentrations in McCoy Branch at MCK 2.0 and MCK 2.05.



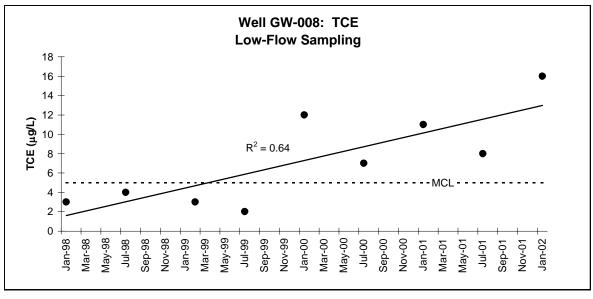


Fig. A.53. Concentrations of PCE and TCE in well GW-008.

08/20/03

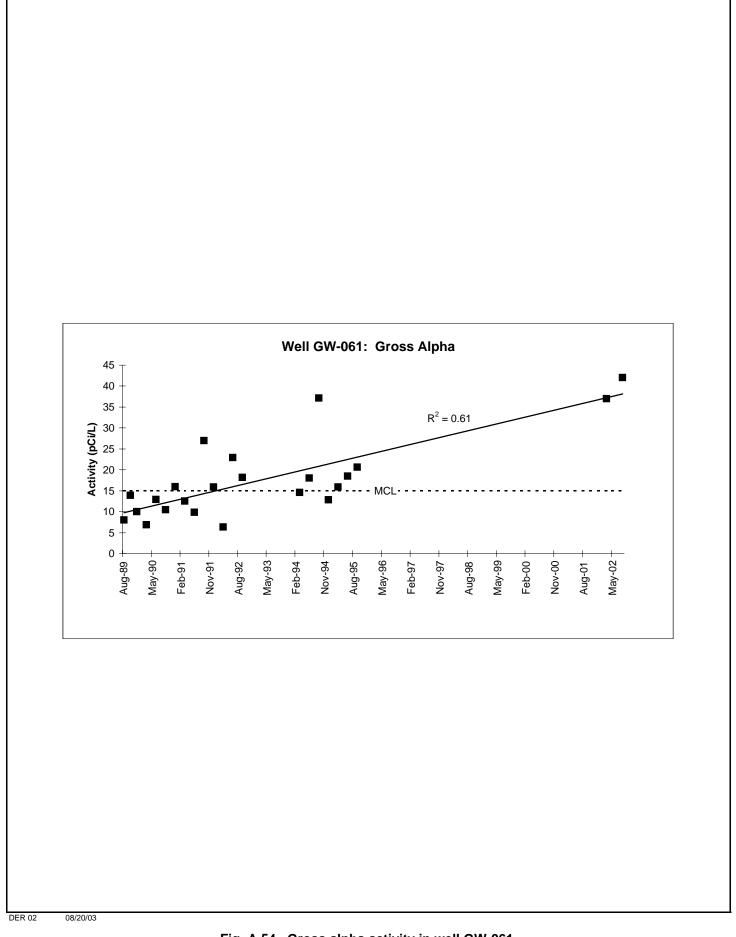
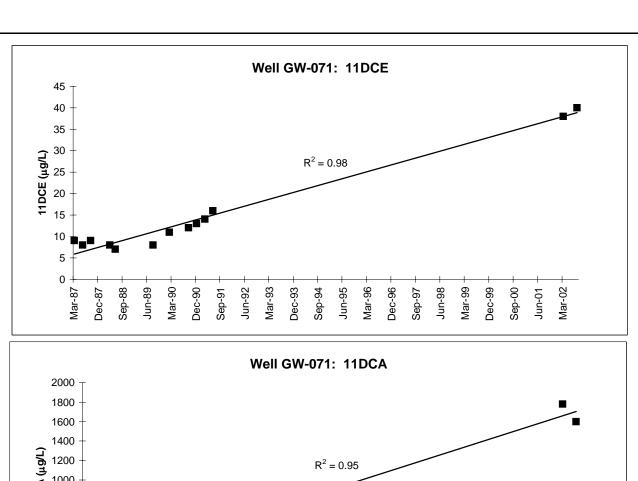
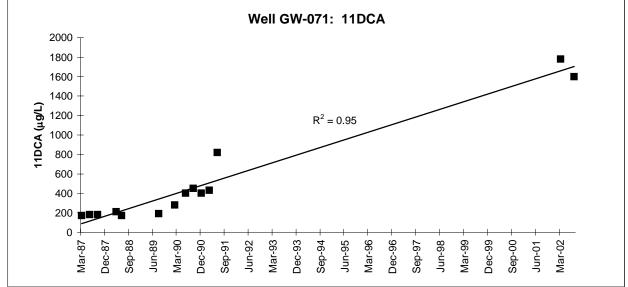


Fig. A.54. Gross alpha activity in well GW-061.





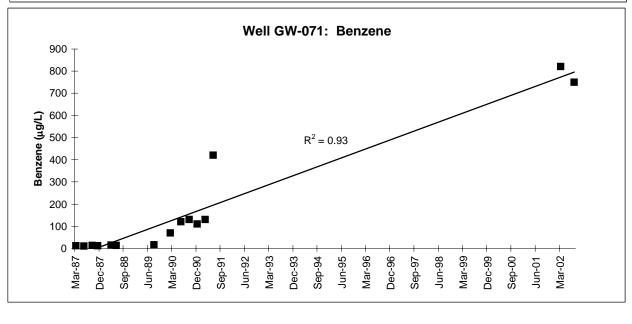
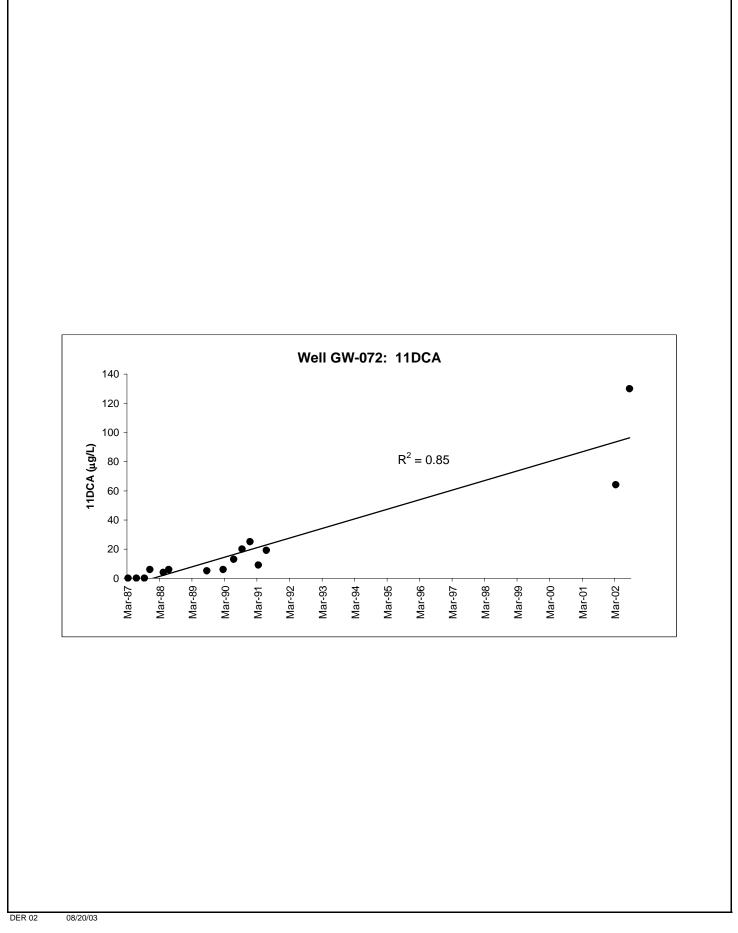
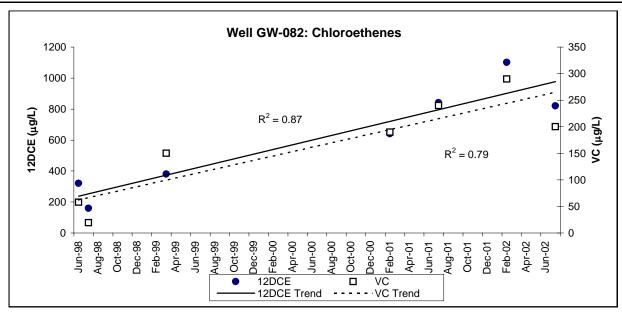
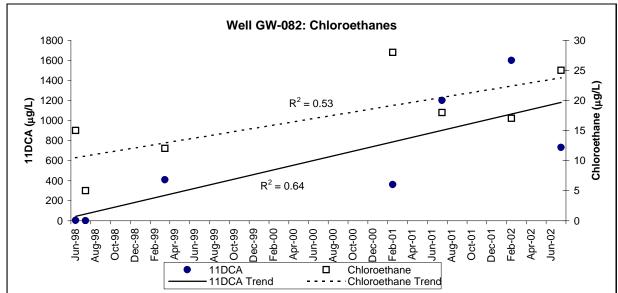


Fig. A.55. Concentrations of selected VOCs in well GW-071.

08/20/03







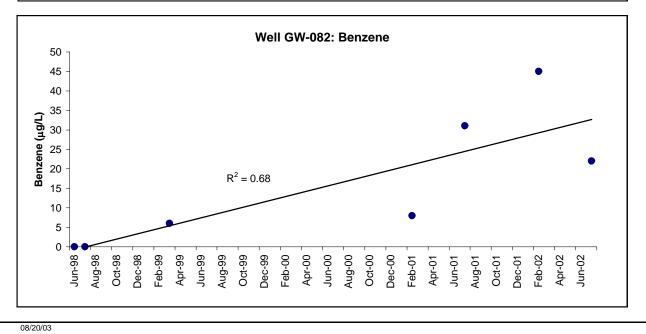


Fig. A.57. Concentrations of selected VOCs in well GW-082.

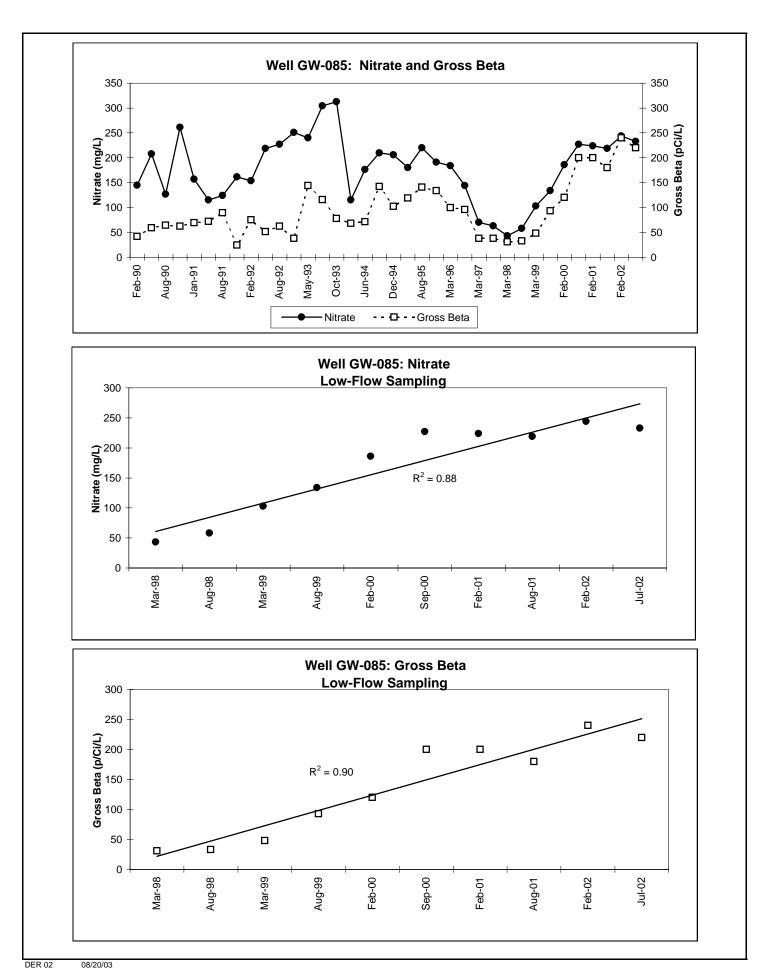
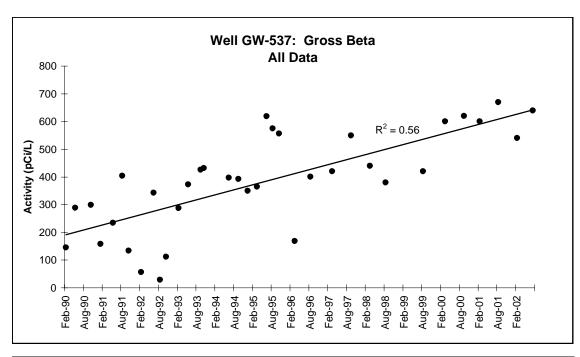


Fig. A.58. Nitrate concentrations and gross beta activity in well GW-085.



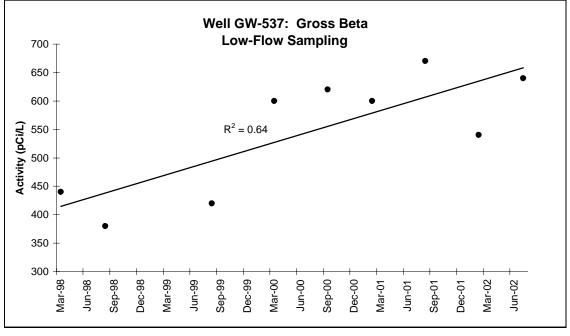
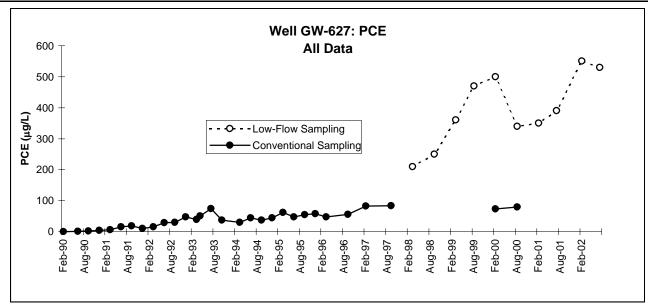
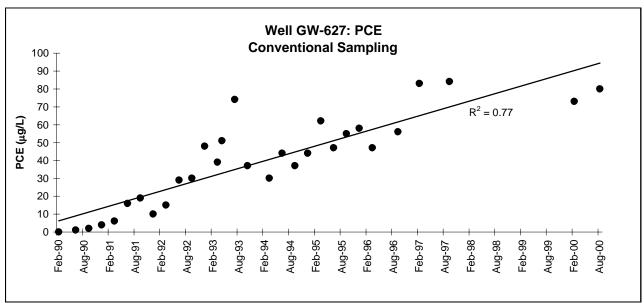


Fig. A.59. Gross beta activity in well GW-537.

08/20/03





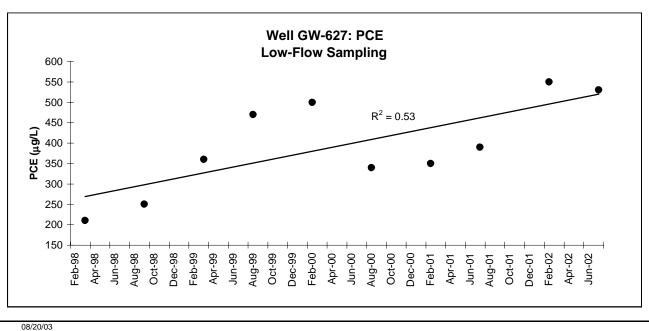
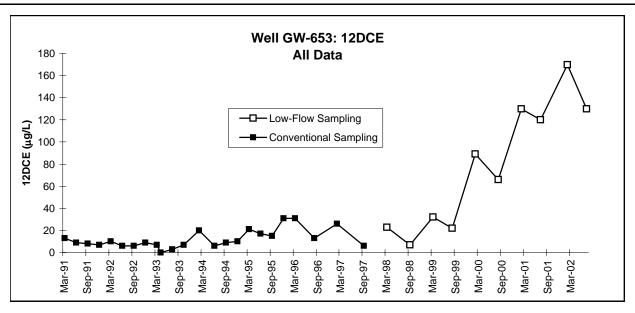
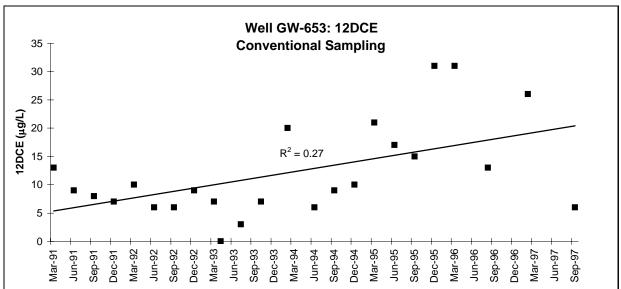


Fig. A.60. Concentrations of PCE in well GW-627.





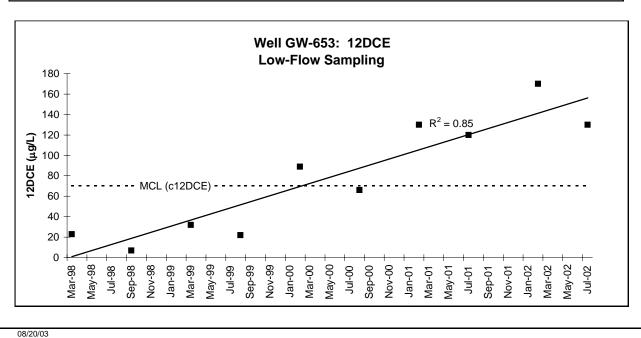
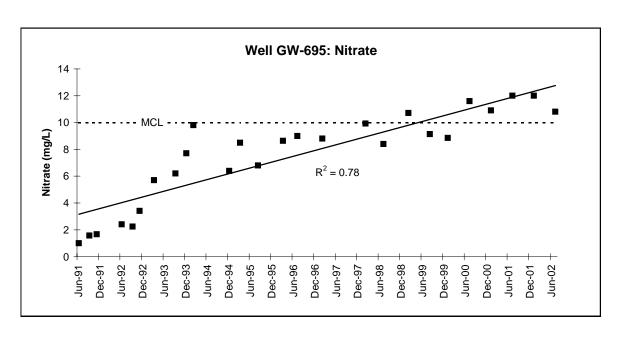


Fig. A.61. Concentrations of 12DCE in well GW-653.



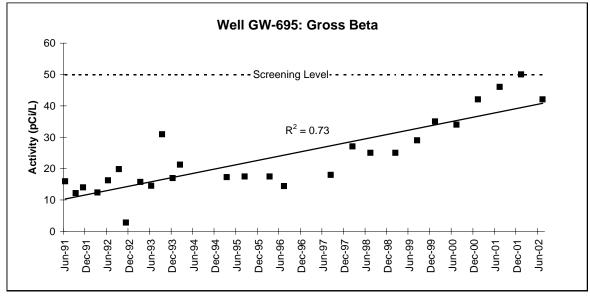
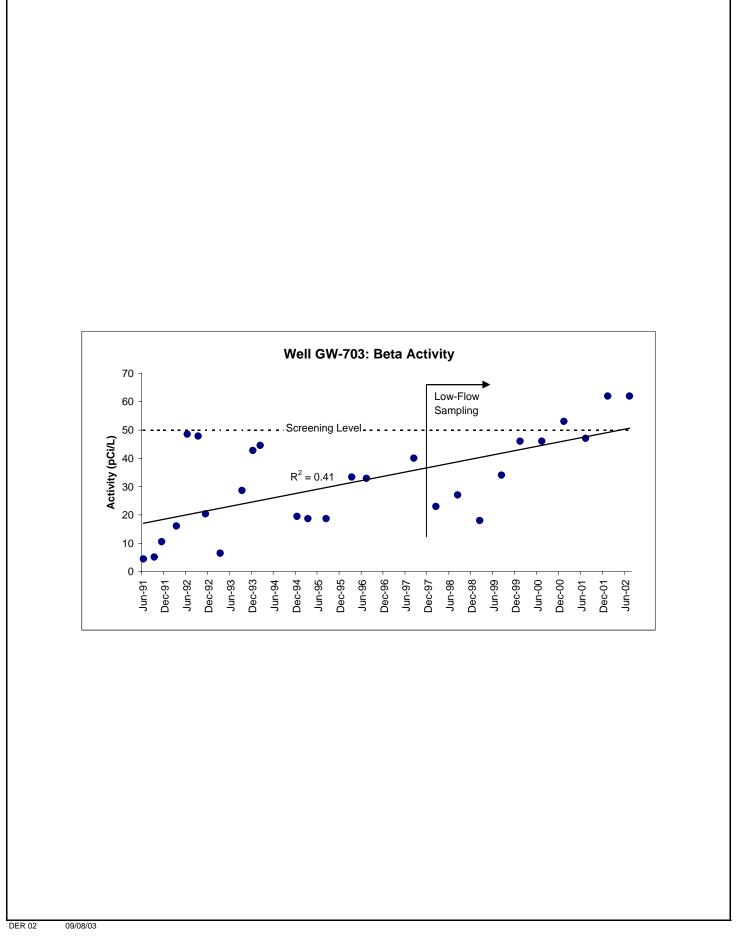
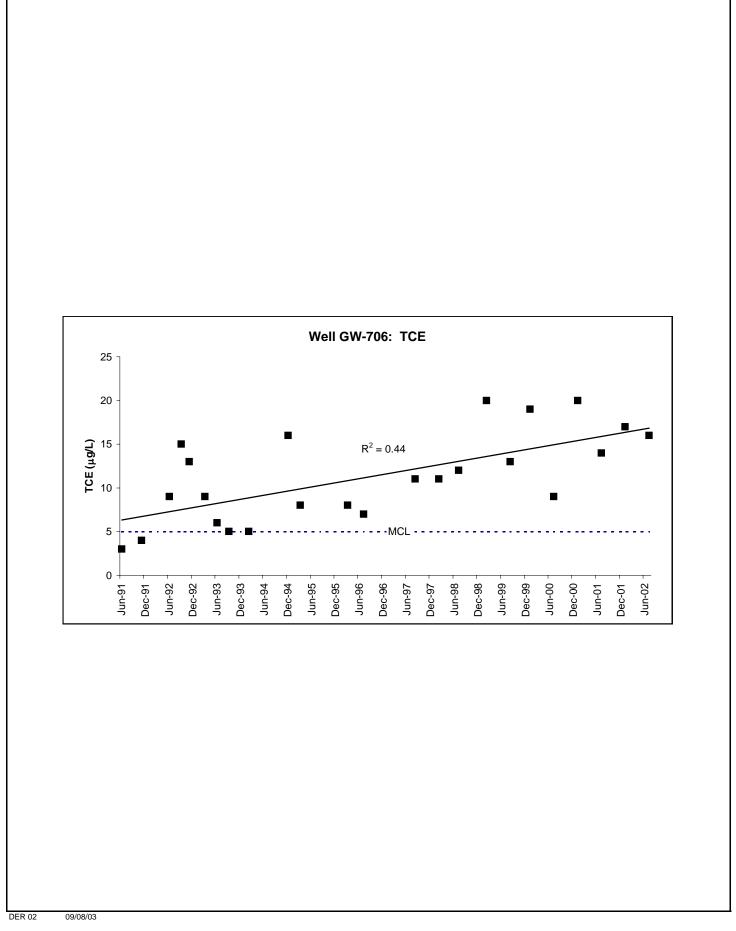
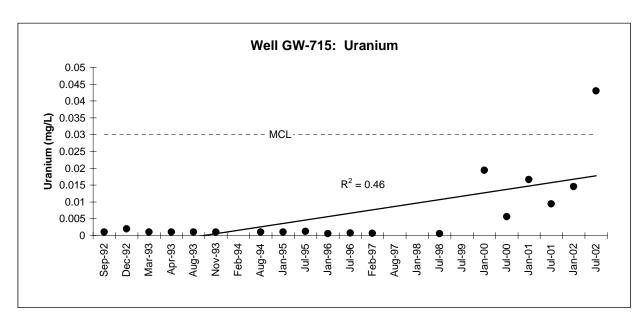


Fig. A.62. Nitrate concentrations and gross beta activity in well GW-695.

08/20/03







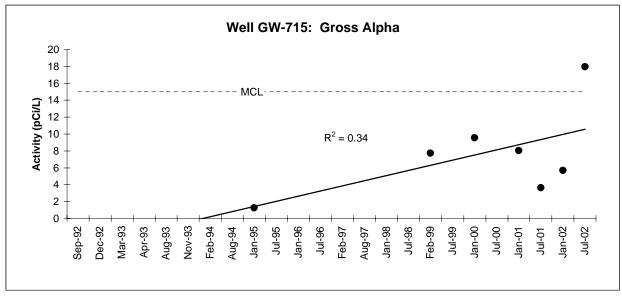
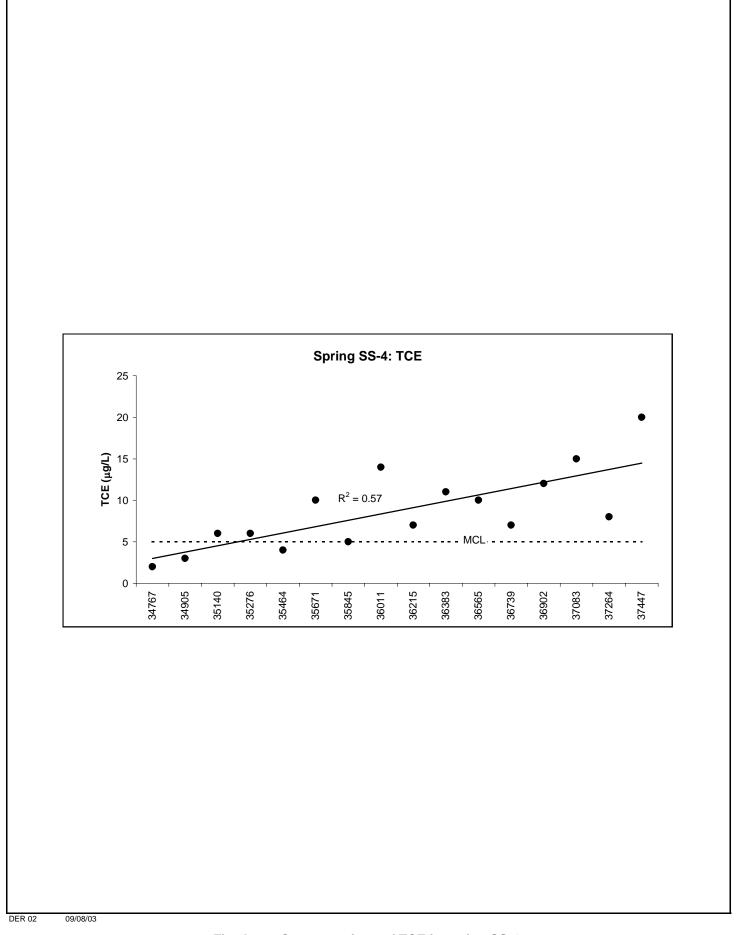


Fig. A.65. Uranium concentrations and gross alpha activity in well GW-715.

09/08/03



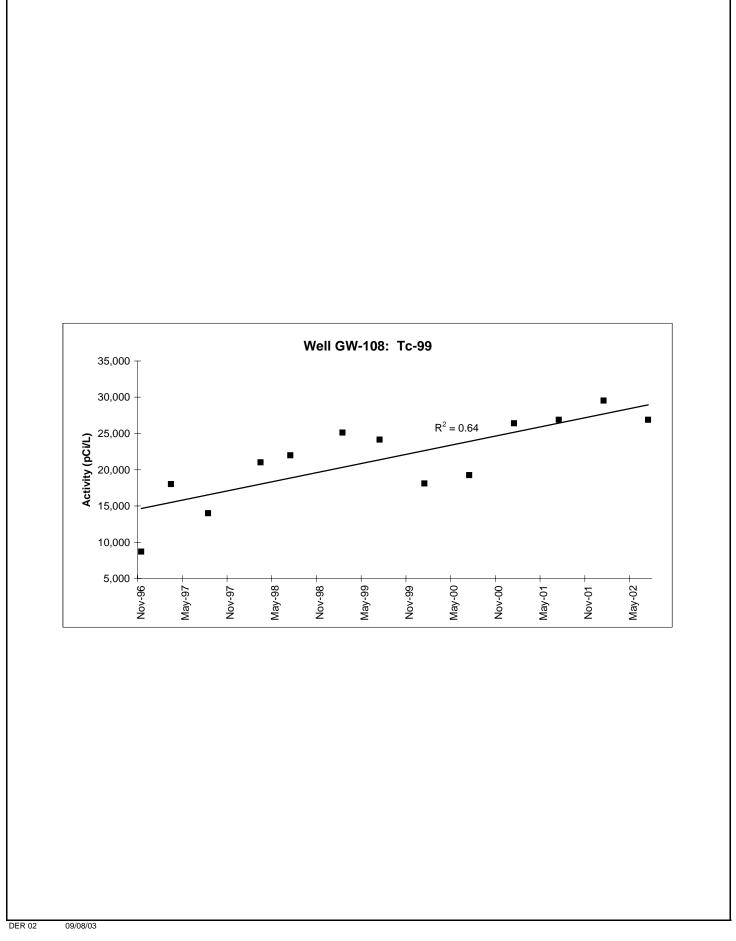
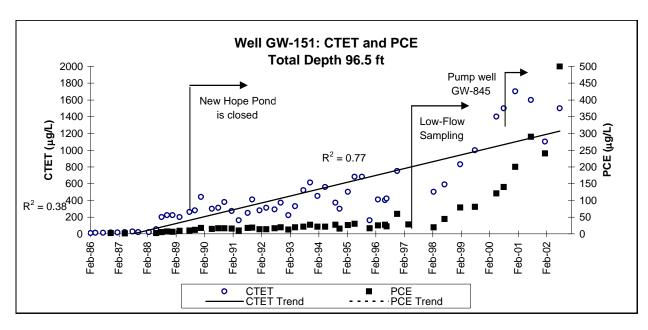


Fig. A.67. Tc-99 activity in well GW-108.



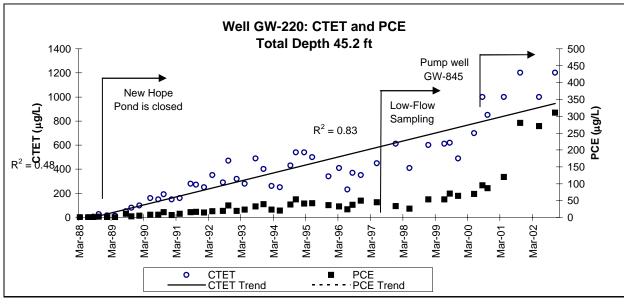
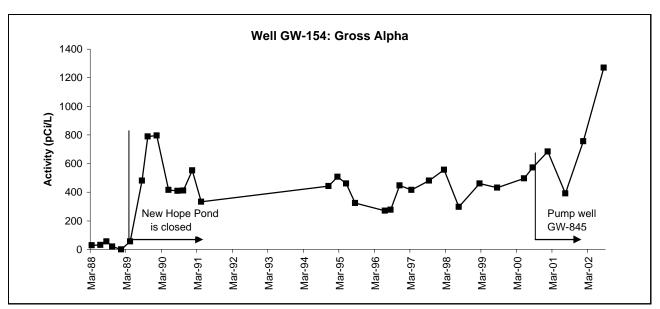
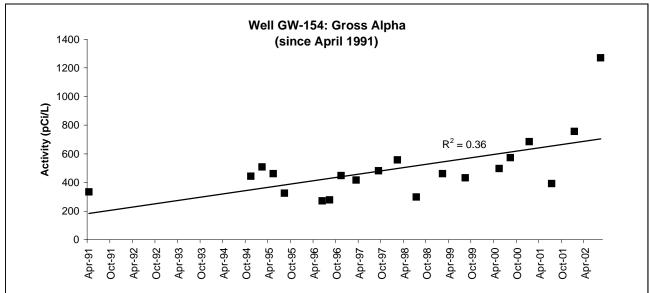


Fig. A.68. Concentrations of CTET and PCE in wells GW-151 and GW-220.

09/08/03





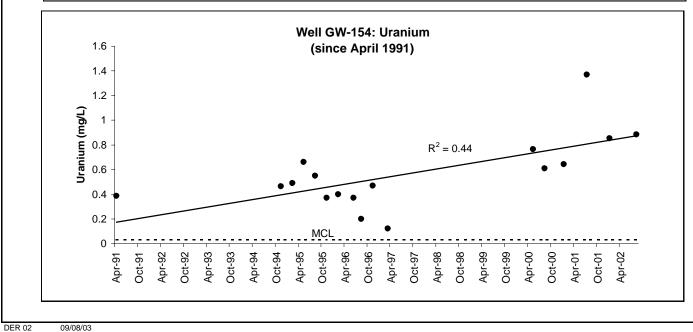
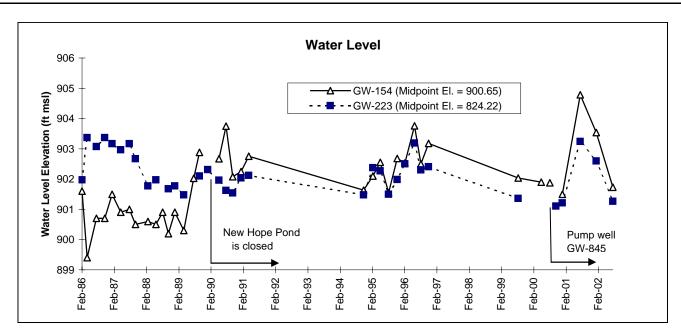
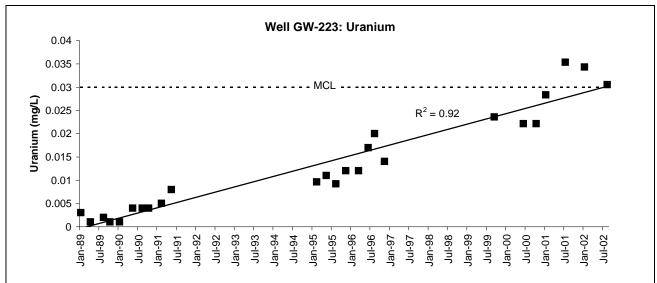


Fig. A.69. Uranium concentrations and gross alpha activity in well GW-154.





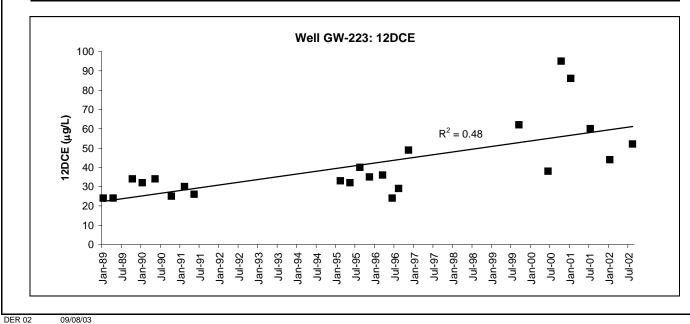


Fig. A.70. Concentrations of uranium and 12DCE in well GW-223.

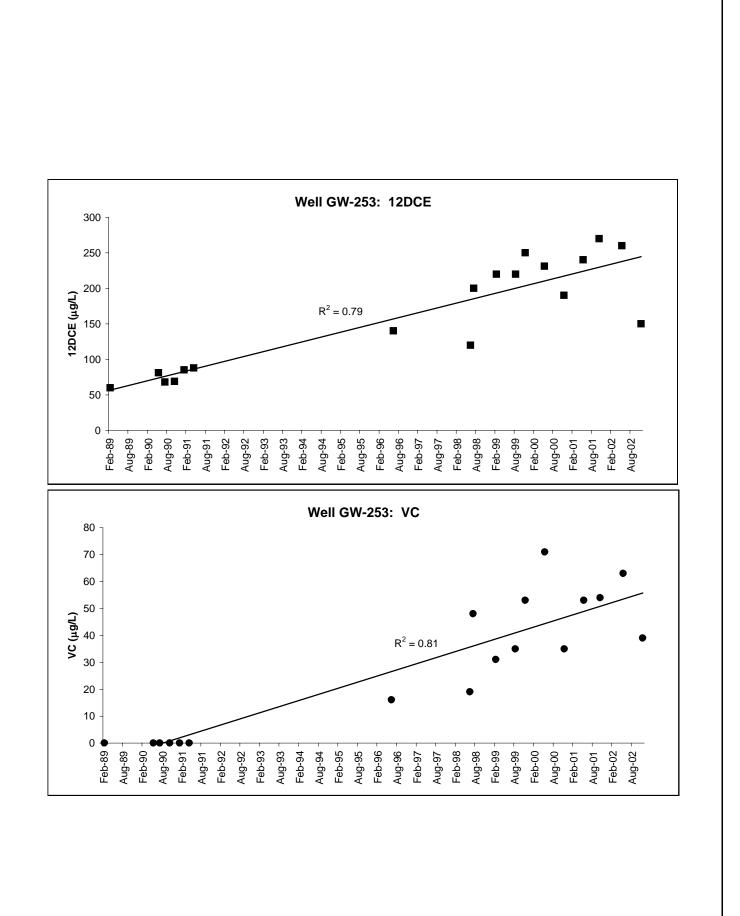


Fig. A.71. Concentrations of 12DCE and VC in well GW-253.

09/08/03

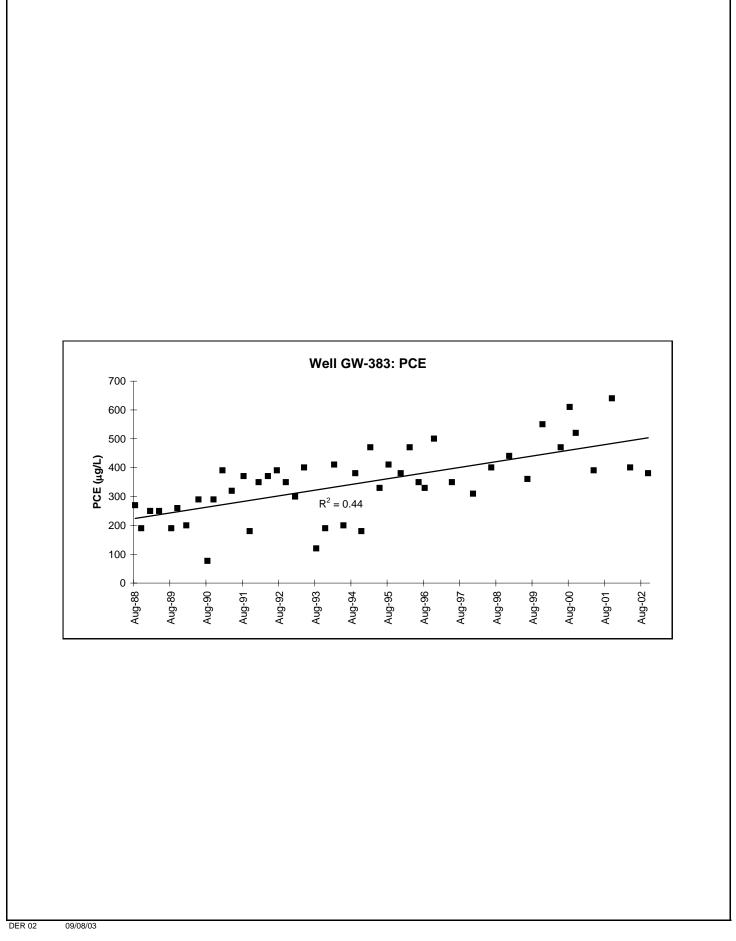


Fig. A.72. Concentrations of PCE in well GW-383.

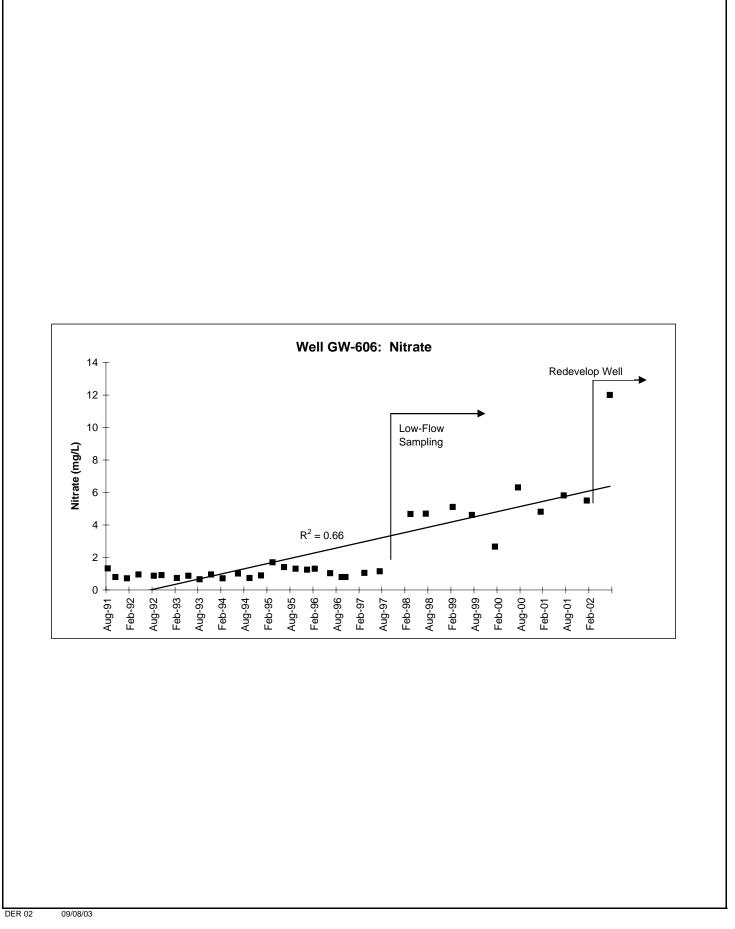


Fig. A.73. Nitrate concentrations in well GW-606.

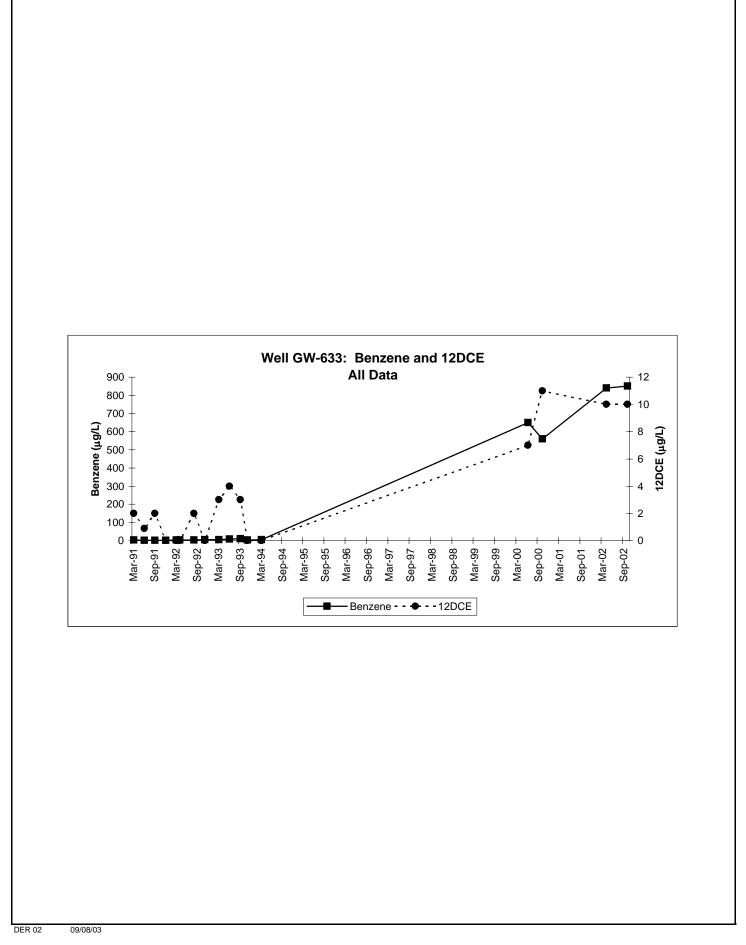
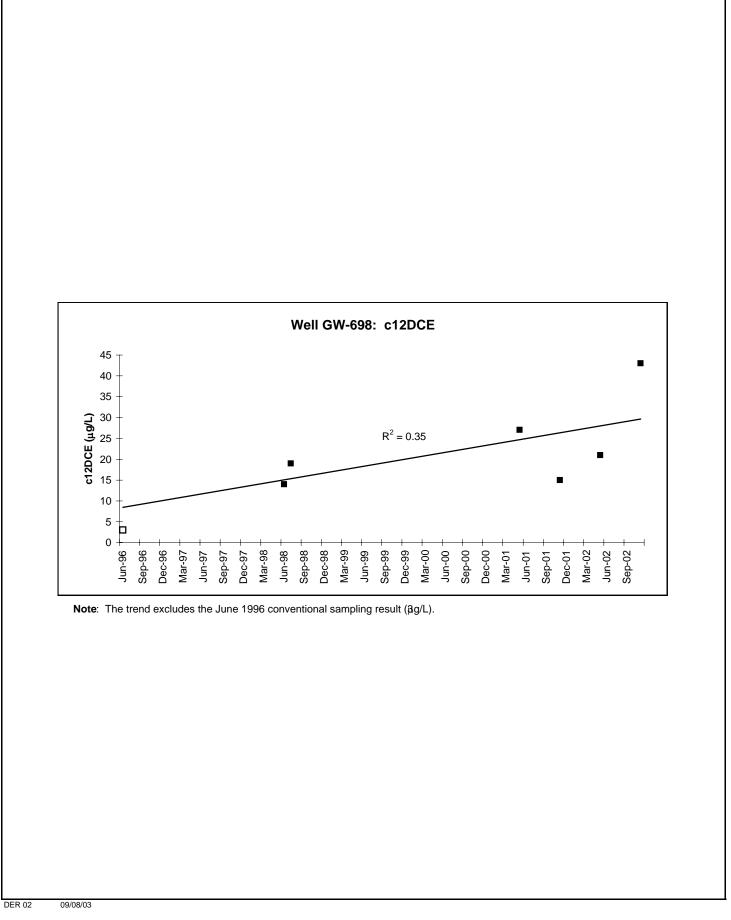
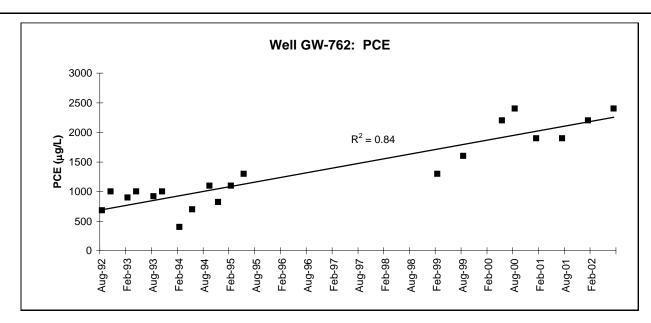
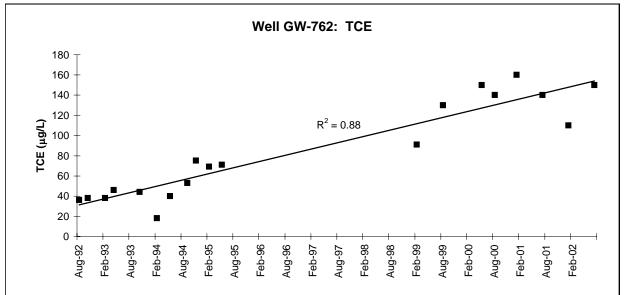


Fig. A.74. Concentrations of benzene and 12DCE in well GW-633.







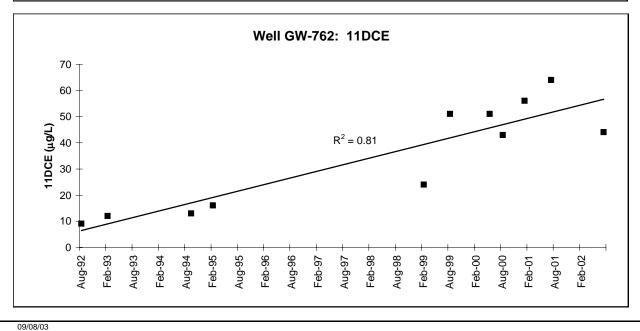


Fig. A.76. Concentrations of PCE, TCE, and 11DCE in well GW-762.

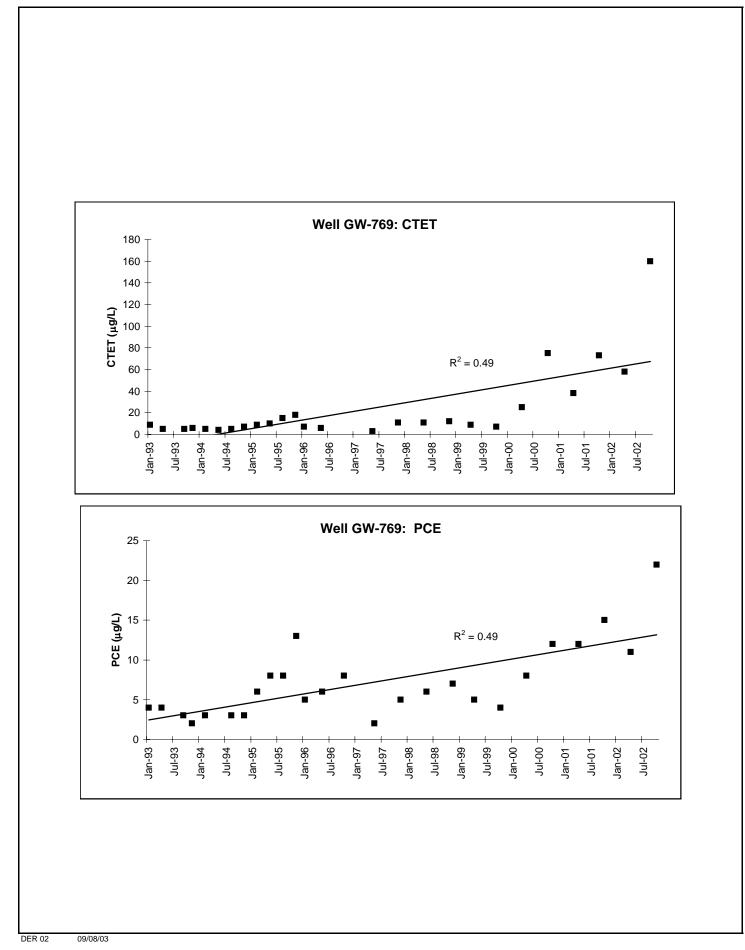


Fig. A.77. Concentrations of CTET and PCE in well GW-769.

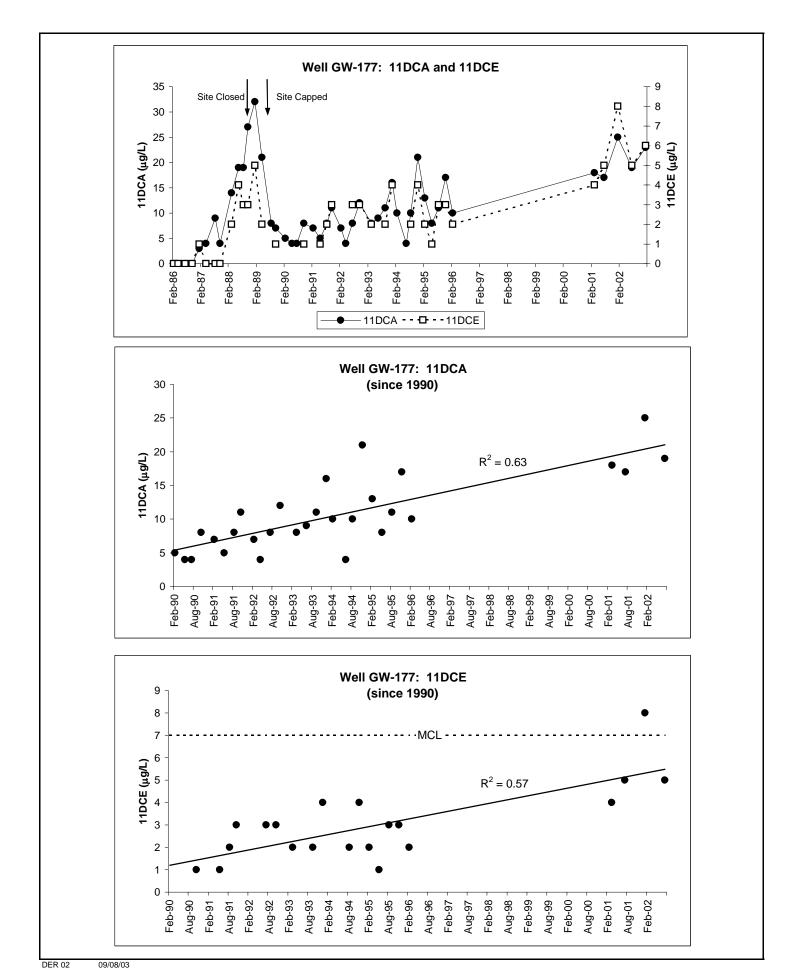
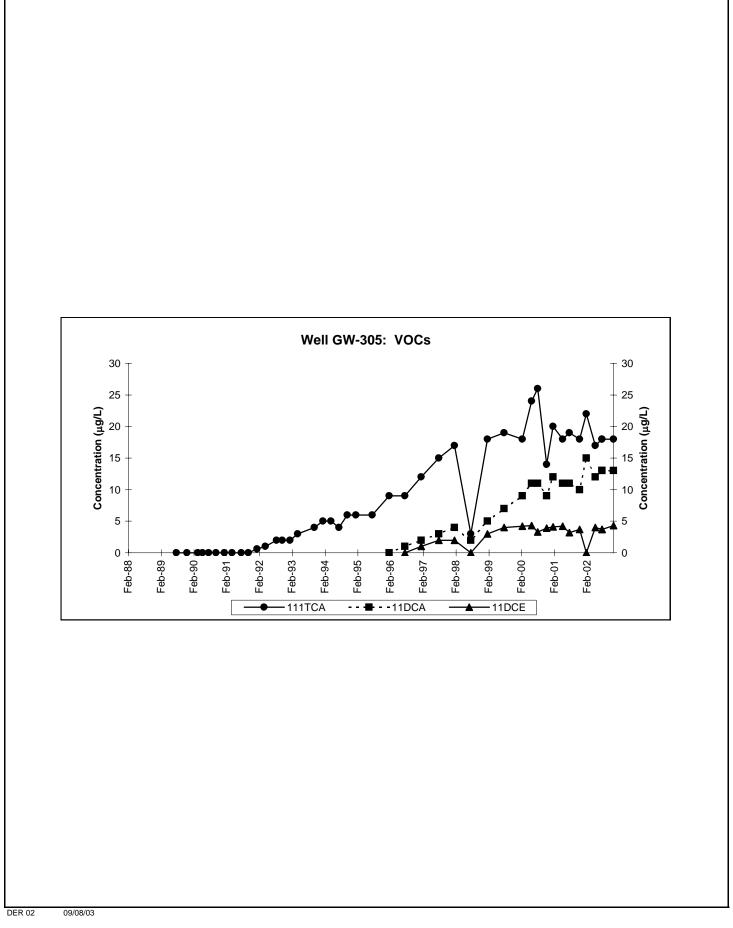
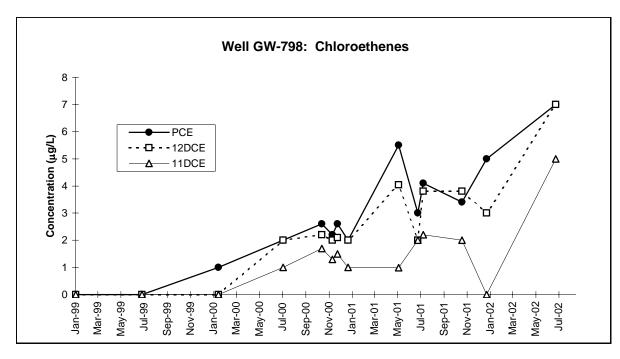


Fig. A.78. Concentrations of 11DCA and 11DCE in well GW-177.





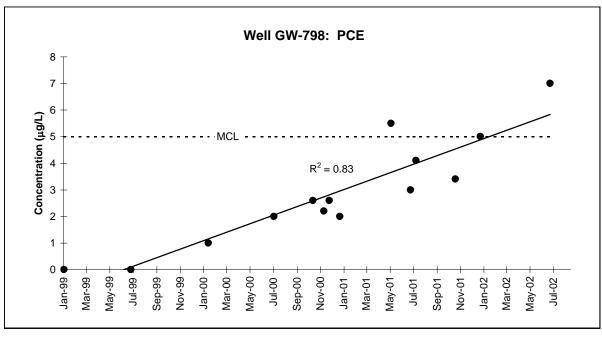


Fig. A.80. Concentrations of PCE, 11DCE, and 12DCE in well GW-798.

09/08/03

APPENDIX B

TABLES

Table B.1. CY 2002 sampling dates for groundwater and surface water sampling locations in the Bear Creek Hydrogeologic Regime

n 5.1)	ction	tion (see S	Trend E				
.)	n 4.1)	(see Section	toring Data Evalu	/Perimeter Moni	Exit Pathway	n Purpose ¹	Evaluatio
		•	ng Data Evaluatio			•	
			npling Date 4			Sampling	Sampling
		Quarter	3rd Quarter	2nd Quarter	1st Quarter	Location ³	Point ²
o	•		07/10/02		01/08/02	EXP-SW	BCK-00.63
	•		09/09/02		03/12/02	EXP-SW	BCK-03.30
	•		07/10/02		01/09/02	EXP-SW	BCK-04.55
•	•		07/10/02		01/08/02	EXP-SW	BCK-07.87
•	•		09/09/02		03/11/02	EXP-SW	BCK-09.20
•	•		07/11/02 D		01/09/02	EXP-SW	BCK-09.40
	•		Dry		03/11/02	EXP-SW	BCK-09.47
•	•		09/09/02		03/11/02	EXP-SW	BCK-11.54
•	•		Dry		03/11/02	EXP-SW	BCK-11.84
•	•		07/11/02		01/09/02	EXP-SW	BCK-11.97
•	•		07/02/02		01/07/02	OLF	GW-008
	•		08/12/02		03/14/02 D	BG	GW-014
	•		07/02/02		01/07/02	BG	GW-046
	•		08/05/02		03/12/02	BG	GW-061
	•		08/13/02 D		03/25/02	OLF	GW-066
			08/05/02		03/11/02	BG	GW-069
	•		08/06/02 D		03/12/02	BG	GW-071
	•		08/06/02		03/11/02	BG	GW-072
	•				03/19/02	OLF	GW-076
	•		08/08/02		02/26/02	BG	GW-077
	•		08/08/02		02/26/02	BG	GW-078
	•		08/07/02 D		02/26/02 D	BG	GW-079
			08/07/02		02/26/02	BG	GW-080
•	•		07/29/02		02/12/02	BG	GW-082
•	•		07/31/02		02/18/02	OLF	GW-085
	•				03/25/02	OLF	GW-087
	•		08/08/02		03/14/02	BG	GW-091
	•		07/08/02		01/07/02	S3	GW-115
	•		08/01/02		02/19/02	OLF	GW-225
	•		08/01/02		02/19/02	OLF	GW-226
	•		08/12/02		03/19/02 D	OLF	GW-229
	•		08/13/02		03/21/02	S3	GW-243
	•		07/08/02		01/07/02	S3	GW-276
			08/07/02		03/13/02	BG	GW-288

Table B.1 (continued)

5.1)	Section	Evaluation (see	Trend				
] [1	itoring Data Eval	/Perimeter Moni	Exit Pathway	n Purpose ¹	Evaluatio
		·	ing Data Evaluati			•	
	1	Carrier in	mpling Date 4			Sampling	Sampling
		4th Quarter	3rd Quarter	2nd Quarter	1st Quarter	Location ³	Point ²
	•		08/08/02		03/13/02	BG	GW-289
	•		08/07/02		03/14/02	BG	GW-291
	•		07/30/02		02/13/02 D	RS	GW-311
	•		07/30/02		02/13/02	SPI	GW-315
	•	12/04/02	08/14/02			EMWMF	GW-363
	•		08/08/02		02/26/02	S3	GW-526
•	•		07/31/02 D		02/18/02	OLF	GW-537
	•		07/25/02		02/11/02	BG	GW-626
•	•		07/29/02		02/11/02	BG	GW-627
	•	12/04/02	08/14/02			EMWMF	GW-639
•	•		07/25/02		02/12/02	BG	GW-653
	•		07/09/02		01/14/02	EXP-A	GW-683
	•		07/09/02 D		01/14/02	EXP-A	GW-684
	•		07/17/02		01/29/02	EXP-B	GW-694
•	•		07/15/02		01/15/02	EXP-B	GW-695
•	•		07/15/02		01/15/02	EXP-B	GW-703
	•		07/16/02		01/16/02 D	EXP-B	GW-704
•	•		07/16/02		01/16/02	EXP-B	GW-706
	•		07/01/02		01/03/02	EXP-W	GW-712
	•		07/01/02		01/03/02	EXP-W	GW-713
	•		07/01/02		01/02/02	EXP-W	GW-714
	•		07/01/02 D		01/02/02 D	EXP-W	GW-715
	•		07/23/02		03/05/02	EXP-C	GW-723
	•		07/23/02		01/30/02	EXP-C	GW-724
	•		07/18/02		01/31/02	EXP-C	GW-725
	•		07/17/02		03/06/02	EXP-C	GW-736
	•		07/18/02		03/06/02	EXP-C	GW-737
	•		07/23/02		01/30/02	EXP-C	GW-738
	•		07/22/02		03/05/02	EXP-C	GW-739
	•		07/22/02	•	01/29/02	EXP-C	GW-740
	•	11/19/02	08/22/02	05/20/02	03/04/02	S3	GW-835
	•	12/10/02	08/15/02			EMWMF	GW-916
	•	12/05/02	08/12/02			EMWMF	GW-917
	•	12/10/02	08/15/02			EMWMF	GW-918

Table B.1 (continued)

		Trend Evaluation (see Section 5.									
Evaluatio	n Purpose ¹	Exit Pathway	y/Perimeter Mon	itoring Data Eva	luation (see Sect	ion 4	.1)				
		Surv	eillance Monitor	ing Data Evaluat	ion (see Section	3.1)					
Sampling	Sampling		CY 2002 Sar	mpling Date 4							
Point ²	Location ³	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter						
GW-919	EMWMF			08/14/02	12/09/02	•					
GW-920	EMWMF			08/13/02	12/05/02	•					
GW-921	EMWMF			08/12/02	12/04/02	•					
GW-922	EMWMF			08/13/02	12/09/02	•					
GW-923	EMWMF			08/14/02	12/09/02	•					
GW-924	EMWMF		•	08/13/02 D	12/10/02 D	•					
GW-925	EMWMF		•	08/12/02	12/04/02	•					
GW-926	EMWMF			08/13/02	12/10/02	•					
GW-927	EMWMF		•	08/12/02	12/05/02	•					
NT-01	EXP-SW	01/09/02		07/11/02			•				
NT-3	EXP-SW	03/11/02	•	Dry			•				
NT-7	EXP-SW	03/13/02		Dry			•				
NT-8	EXP-SW	03/13/02		Dry			•				
NT-8-E	EXP-SW	03/13/02	•	Dry			•				
NT-8-W	EXP-SW	03/13/02		Dry			•				
S07(NT-02)	EXP-SW	03/11/02	•	Dry			•				
SS-1	EXP-SW	01/09/02		07/15/02			•				
SS-4	EXP-SW	01/08/02		07/10/02			•	•			
SS-5	EXP-SW	01/08/02 D	•	07/10/02			•				
SS-6	EXP-SW	01/08/02		07/10/02			•				
SS-7	EXP-SW	03/12/02		Dry			•				
SS-8	EXP-SW	03/12/02 D		09/09/02 D			•				

- 1 Although samples were collected from the sampling locations for a variety of monitoring purposes (e.g., RCRA), this report uses all of the monitoring results for DOE Order 5400.1 data evaluation. The monitoring program for each location is provided in the CY 2001 GWMR (Elvado Environmental LLC. 2003).
- 2 **BCK** Bear Creek Kilometer

GW Groundwater Monitoring Well NT Northern Tributary (to Bear Creek) S07 Surface water location in NT-2

Spring sampling location (south side of Bear Creek) SS

Table B.1 (continued)

Notes: (continued)

3 BG Bear Creek Burial Grounds Waste Management Area **EMWMF** Environmental Management Waste Management Facility

Exit Pathway (Maynardville Limestone) Picket A

MWMF EXP-A EXP-B EXP-C EXP-W -Exit Pathway Picket B Exit Pathway Picket C EXP-W Exit Pathway Picket W

EXP-SW Exit Pathway (Bear Creek) Surface Water Oil Landfarm Waste Management Area OLF

RS Rust Spoil Area SPI Spoil Area I S-3 Site **S**3

Not sampled

D Duplicate sample collected on specified date (shown in bold typeface)

Table B.2. CY 2002 sampling dates for groundwater and surface water sampling locations in the Upper East Fork Poplar Creek Hydrogeologic Regime

ction 5.2)	Sec	Evaluation (see	Trend				
		`	onitoring Data Eva	ay/Perimeter Mo	Exit Pathw	Purpose ¹	Evaluation l
		· · · · · · · · · · · · · · · · · · ·	toring Data Evaluat	-		· ·	
		·	ampling Date 4			Sampling	Sampling
		4th Quarter	3rd Quarter	2nd Quarter	1st Quarter	Location ³	Point ²
	•	10/14/02		04/17/02 D		GRIDB2	55-1B
•		10/29/02		05/15/02		EXP-NPR	GHK2.51ESW
•		10/29/02 D		05/15/02		EXP-NPR	GHK2.51WSW
•	•		07/09/02		01/08/02	S3	GW-108
•			08/05/02		01/30/02	NHP	GW-151
,	•	10/21/02		04/25/02		NHP	GW-153
,	•		08/05/02		01/30/02	NHP	GW-154
•		11/11/02	08/06/02	05/13/02	02/04/02	EXP-UV	GW-169
•		11/11/02 D	08/06/02 D	05/14/02 D	02/04/02 D	EXP-UV	GW-170
•			08/07/02		02/05/02	EXP-UV	GW-171
•			08/07/02		02/05/02	EXP-UV	GW-172
•			07/09/02		01/08/02	T2331	GW-193
,	•	11/06/02		05/02/02		T0134	GW-204
•		11/19/02 D		05/08/02		EXP-SR	GW-207
•		11/19/02		05/08/02		EXP-SR	GW-208
,	•	11/07/02 D		05/06/02		UOV	GW-219
•		11/21/02		05/14/02		NHP	GW-220
,	•		08/05/02		01/31/02	NHP	GW-223
•			08/07/02		02/05/02	EXP-UV	GW-230
•		11/11/02	08/06/02	05/13/02	02/04/02	EXP-UV	GW-232
,	•			04/18/02		S2	GW-251
,	•	11/07/02		05/07/02		S2	GW-253
,	•	10/14/02		04/16/02		S2	GW-349
,	•	10/15/02 D		04/16/02		S2	GW-350
,	•		08/05/02	. 1	02/04/02	NHP	GW-380
,	•	10/22/02		04/24/02 *		NHP	GW-381
,	•		08/06/02		02/04/02	NHP	GW-382
,	•	10/22/02		04/25/02		NHP	GW-383
•	•		07/08/02 D		01/08/02 D	EXP-I	GW-605
•	•		07/08/02		01/08/02	EXP-I	GW-606
,	•	11/07/02		05/09/02		EXP-E	GW-618
,	•	10/15/02		04/23/02		FTF	GW-620
,	•	10/17/02		04/23/02		RG	GW-633
,	•	10/17/02		04/24/02		FF	GW-658
,	•	11/14/02 C		. 1		СРТ	GW-686
,	•	11/14/02 C				СРТ	GW-687

Table B.2 (continued)

Trend Evaluation (see Section 5	Trend				
ng Data Evaluation (see Section 4.2)	Ionitoring Data Ev	ay/Perimeter M	Exit Pathwa	Purpose ¹	Evaluation 1
Pata Evaluation (see Section 3.2)	toring Data Evalua	rveillance Monit	Sur	_	
	ampling Date 4			Sampling	Sampling
Quarter 4th Quarter	3rd Quarter	2nd Quarter	1st Quarter	Location ³	Point ²
. 11/14/02 C ●			•	CPT	GW-689
. 11/07/02		05/02/02 D		B8110	GW-698
7/15/02 11/07/02 •	07/15/02	05/23/02	02/04/02	EXP-J	GW-722-06
7/16/02 11/12/02 •	07/16/02	05/29/02	02/06/02	EXP-J	GW-722-10
7/17/02 11/13/02 •	07/17/02	05/30/02	02/08/02	EXP-J	GW-722-14
7/17/02 11/13/02 •	02/08/02 06/03/02 07/17/02 11/13/02		EXP-J	GW-722-17	
17/02 D 11/12/02 ●			EXP-J	GW-722-20	
7/16/02 11/12/02 •	07/16/02	05/30/02	02/07/02 D	EXP-J	GW-722-22
7/15/02 11/11/02 D •	07/15/02	05/28/02 D	02/05/02	EXP-J	GW-722-26
7/15/02 11/11/02 •	07/15/02	05/28/02	02/05/02	EXP-J	GW-722-30
7/15/02 11/12/02	07/15/02	05/28/02	02/05/02	EXP-J	GW-722-32
	07/16/02	05/29/02	02/06/02	EXP-J	GW-722-33
1/09/02 .	07/09/02		01/08/02	EXP-J	GW-733
. 11/21/02		05/14/02		EXP-J	GW-735
. 11/18/02		05/07/02		GRIDK1	GW-744
. 11/20/02		05/09/02		GRIDK2	GW-747
. 11/20/02		05/05/02		EXP-J	GW-750
31/02 D .	07/31/02 D		01/31/02 D	GRIDJ3	GW-762
. 10/21/02		04/18/02 *		GRIDJ3	GW-763
. 10/30/02		04/29/02		GRIDG3	GW-769
. 10/30/02		04/29/02		GRIDG3	GW-770
. 10/31/02		04/30/02		GRIDH3	GW-775
. 10/31/02		04/30/02		GRIDH3	GW-776
. 11/04/02		05/01/02		GRIDE3	GW-782
. 11/06/02		05/01/02		GRIDD2	GW-791
. 11/18/02		05/07/02		EXP-SR	GW-816
	08/05/02		01/31/02	NHP	GW-832
. 11/19/02		05/06/02 D		EXP-SW	LRSPW
. 10/29/02		05/15/02		EXP-NPR	NPR07.0SW
. 10/29/02	•	05/15/02 D	•	EXP-NPR	NPR12.0SW
. 10/29/02		05/15/02		EXP-NPR	NPR23.0SW
	09/03/02		02/14/02	EXP-SW	OF 51
	08/20/02 S		02/01/02 S	EXP-SW	OF 200
	07/11/02		02/11/02	EXP-UV	SCR7.1SP
	07/11/02		02/11/02	EXP-UV	SCR7.8SP
	08/20/02 S		02/01/02 S	EXP-SW	STATION 17
	08/20/02 S		02/01/02 S	EXP-SW	STATION 8

Table B.2 (continued)

Notes:

Although samples were collected from the sampling locations for a variety of monitoring purposes (e.g., RCRA), this report uses all of the monitoring results for DOE Order 5400.1 data evaluation. The monitoring program for each location is provided in the CY 2002 GWMR (Elvado Environmental LLC. 2003).

2 GHK - Gum Hollow Branch Kilometer

GW - Groundwater Monitoring Well (also 55-1B)

LRSPW - Outfall of the New Hope Pond distribution channel underdrain

NPR - North of Pine Ridge near the Scarboro Community

OF - Storm drain outfall

SCR - Spring sampling location in Union Valley

SP - Spring sampling location (suffix)

STATION - Surface water sampling location in Upper East Fork Poplar Creek

SW - Surface water sampling location (suffix)

3 B8110 - Building 81-10

CPT - Coal Pile Trench

EXP - Exit Pathway monitoring location:

-E, -I, or -J: Maynardville Limestone Picket monitoring well.

-NPR: Surface water station located north of Pine Ridge where drainage exits the ORR.

-SW: Onsite surface water station

-SR: Along Scarboro Road in the gap through Pine Ridge

-UV: East of the Oak Ridge Reservation boundary in Union Valley

FF - Fuel Facility (Building 9754-2)

FTF - Fire Training Facility

GRID - Comprehensive Groundwater Monitoring Plan Grid Location

NHP - New Hope Pond RG - Rust Garage Area

S2 - S-2 Site S3 - S-3 Site T0134 - Tank 0134-U T2331 - Tank 2331-U

UOV - Uranium Oxide Vault

4 . - Not sampled.

C - Conventional sampling method used (three well-volume purge)

D - Duplicate sample collected on specified date (shown in bold typeface).

* - Resampled on 06/12/02 for organics analyses.

S - Two sets of samples were collected: a stormflow sample on the date shown (within six hours after a 0.5-inch or more rainfall) and a baseflow sample collected later (02/14/02 during the first quarter and 09/03/02 during the third quarter).

Table B.3. CY 2002 sampling dates for groundwater and surface water sampling locations in the Chestnut Ridge Hydrogeologic Regime

			Trend Evaluation (see Section 5.									
Evaluatio	n Purpose ¹	Exit Pathwa	ay/Perimeter Monit	toring Data Evalı	uation (see Sect	ion 4.2	2)					
		Sur	veillance Monitorii	ng Data Evaluati	on (see Section	3.3)						
Sampling	Sampling		CY 2002 Samp	pling Date ⁵								
Point ³	Location 4	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter							
1090	UNCS	01/30/02		07/30/02		•						
GW-141	LIV	01/23/02		07/25/02		•						
GW-142	KHQ		04/10/02		10/16/02	•						
GW-143	KHQ		04/09/02		10/16/02	•						
GW-144	KHQ		04/09/02		10/16/02	•						
GW-145	KHQ		04/08/02		10/21/02	•						
GW-156	CRSDB		04/15/02 D		10/14/02 D	•						
GW-159	CRSDB		04/15/02		10/16/02	•						
GW-177	CRSP	01/09/02		07/10/02		•	•					
GW-203	UNCS	01/29/02		07/30/02		•						
GW-205	UNCS	01/30/02		07/30/02		•						
GW-217	LIV	01/22/02 *		07/22/02		•						
GW-221	UNCS	01/29/02		07/30/02		•						
GW-231	KHQ		04/08/02 D		10/17/02 D	•						
GW-301	CRBAWP	01/09/02 D		07/10/02 D		•						
GW-302	UNCS	01/31/02		07/31/02		•						
GW-305	LIV	01/22/02 *	05/02/02	07/15/02	11/21/02	•	•					
GW-339	UNCS	01/29/02 D		07/30/02 D		•						
GW-521	LIV	01/10/02		07/15/02		•						
GW-522	LIV	01/22/02 *		07/15/02		•						
GW-539	LII	01/14/02		07/17/02		•						
GW-540	LII/CDLVII	01/16/02		07/18/02		•						
GW-542	CDLVI	01/16/02		07/18/02		•						
GW-543	CDLVI	01/15/02		07/18/02		•						
GW-544	CDLVI	01/15/02		07/22/02		•						
GW-557	LV	01/10/02 D		07/11/02 D		•						
GW-560	CDLVII	01/17/02		07/16/02		•						
CW 562	CDLVIII	01/09/02		07/10/02								
GW-562	CDLVII	01/22/02 *	•	07/16/02								
GW-564	CDLVII	01/16/02 D		07/16/02 D		•						
GW-709	LII	01/15/02		07/17/02		•						
GW-731	CRSDB		04/16/02		10/15/02	•						
GW-732	CRSDB		04/16/02	•	10/15/02	•						

Table B.3 (continued)

			Trend Evaluation (see								
Evaluation	n Purpose 1	Exit Pathwa	ny/Perimeter Monit	oring Data Evalu	uation (see Sect	ion 4	1.2)				
		Sur	veillance Monitorir	ng Data Evaluati	on (see Section	3.3)					
Sampling	Sampling		CY 2002 Sampling Date ⁵								
Point ³	Location 4	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter						
GW-757	LII	01/15/02		07/17/02		•					
GW-796	LV	01/14/02		07/11/02		•					
GW-797	LV	01/14/02		07/11/02		•					
CW 700	CDLVII	01/09/02		07/10/02							
GW-798	CDLVII	01/16/02		07/16/02		•					
GW-799	LV	01/10/02		07/11/02		•					
GW-801	LV	01/14/02		07/15/02		•					
GW-827	CDLVI	01/17/02		07/18/02		•					
GW-831	FCAP	01/09/02		07/09/02		•					
MCK 2.0	FCAP	02/21/02		07/09/02			•				
MCK 2.05	FCAP	02/21/02 D		07/09/02 D			•				
SCR1.25SP	EXP	02/21/02		07/10/02			•				
SCR1.5SW	EXP	02/21/02 D		08/19/02			•				
SCR2.2SW	EXP	03/21/02		09/23/02			•				
SCR3.5SP	EXP	02/21/02		07/10/02			•				
SCR4.3SP	LV	01/14/02		07/15/02			•				
SCR4.4SW	EXP	02/21/02		09/23/02 D			•				
SCR5.2SP	EXP	02/21/02		08/19/02			•				

- Although samples were collected from the sampling locations for a variety of monitoring purposes (e.g., RCRA), this report uses all of the monitoring results for DOE Order 5400.1 data evaluation. The monitoring program for each location is provided in the CY 2002 GWMR (Elvado Environmental LLC. 2003).
- 2 GW Groundwater monitoring well (also 1090)

MCK - McCoy Branch Kilometer
SCR - South Chestnut Ridge (prefix)
SP - Spring sampling location (suffix)

SW - Surface water sampling location (suffix)

Table B.3 (continued)

Notes: (continued)

3 CDLVI - Construction/Demolition Landfill VI CDLVII - Construction/Demolition Landfill VII

CRBAWP - Chestnut Ridge Borrow Area Waste Pile (formerly)

CRSDB - Chestnut Ridge Sediment Disposal Basin

CRSP - Chestnut Ridge Security Pits

EXP - Exit Pathway (spring or surface water sampling location)

FCAP - Filled Coal Ash Pond
KHQ - Kerr Hollow Quarry
LII - Industrial Landfill II
LIV - Industrial Landfill IV
LV - Industrial Landfill V

UNCS - United Nuclear Corporation Site

4 . - Not Sampled.

D - Duplicate sample collected on specified date (shown in bold typeface).

Groundwater samples were collected for organics analyses from wells GW-217, GW-305, GW-522, and GW-562 on January 28, 2002.

Table B.4 Concentration trends for the principal contaminants detected at CY 2002 sampling locations in the Bear Creek Hydrogeologic Regime

CY 2002		(0			and Long-Terr increasing, —	m Trend ² = decreasing)		
Sampling Location ¹	Inor	ganics ³		V	OCs ⁴		Radioa	ctivity ⁵
Location	Nitrate	Uranium	Ethenes	Ethanes	Methanes	Petroleum	Alpha	Beta
BCK-03.30	•	0					NA	
BCK-04.55		0					0	
BCK-07.87	0	0				•	0	0
BCK-09.20	0	0				•	NA	
BCK-09.40	0	0	0				0	0
BCK-09.47	0	0	0				NA	0
BCK-11.54	0	0					NA	0
BCK-11.84	0	0					NA	0
BCK-11.97	0	0					0	0
GW-008			E	0				
GW-014			-	-			•	
GW-046			0	0		_		
GW-061	0	0					[0
GW-066			_					
GW-071			[, –	[, –		Ε		
GW-072			0	Γ				
GW-082			Е			Ε		
GW-085	Г					•	•	Г
GW-087			-				-	
GW-225	0	•	-					
GW-226	0	•	-					
GW-229		0	0	0		0	0	0
GW-243	0	-	0	0	0		-	-
GW-276	•	-	-				-	0
GW-288			-		•	•		
GW-289			0		•	•		
GW-291			-					
GW-315	•		-		•	•	•	•
GW-526	0			•				
GW-537	0					•		[
GW-626		•	0	0	0	0		
GW-627		•		[•	•	0	
GW-653	•	•		[•	•		
GW-683	0	0				•	0	
GW-684		0				•	0	
GW-694		_				•	_	
GW-695			0	<u> </u>		•		
GW-703	0	•	_			•		<u> </u>
GW-704	0		-			•		
GW-706	0	0					0	0
GW-715		[•	<u> </u>	

Table B.4 (continued)

CY 2002		(0			and Long-Teri increasing, =	m Trend ² = decreasing)		
Sampling Location ¹	Inor	ganics ³		V	OCs ⁴		Radioa	ctivity 5
Location	Nitrate	Uranium	Ethenes	Ethanes	Methanes	Petroleum	Alpha	Beta
GW-723			0				•	
GW-724	0		0					
GW-725	-		-		0			
GW-736	_		-	•			0	0
GW-737	-		-					
GW-738	_		-	•			•	0
GW-739			0					
GW-740			0					
GW-835	_	0	0				NA	NA
NT-01	0	0	0		0		0	0
NT-07			0	0			NA	NA
NT-08		0	0				NA	NA
NT-8-E		0	•	•			NA	NA
S07	0	NA		•			NA	NA
SS-1	0	0					0	0
SS-4	0	0	[0	0
SS-5	0	0	0				0	0

- Only CY 2002 sampling locations with contaminated samples (see criteria below) are included on the table. The exit pathway/perimeter monitoring locations are in bold typeface. Uncontaminated samples (contaminant levels below the criteria) were collected from the following locations in CY 2002: BCK-00.63, GW-069, GW-076, GW-077, GW-078, GW-079, GW-080, GW-091, GW-115, GW-311, GW-363, GW-639, GW-712, GW-713, GW-714, GW-916, GW-917, GW-918, GW-919, GW-920, GW-921, GW-922, GW-923, GW-924, GW-925, GW-926, GW-927, NT-03, NT-8-W, SS-6, SS-7, and SS-8.
- 2 Trend types were interpreted from data tables or plots of concentration changes over time.
 - Not a contaminant (criteria defined below, in notes 3, 4, and 5).
 - Indeterminate trend: insufficient data, fairly stable trend, affected by sampling methods or highly fluctuating with no clear upward or downward trend.
 - Generally decreasing trend.
 - **C** Generally increasing tend.
 - NA Not analyzed.
- 3 CY 2002 nitrate concentration greater than or equal to 10 mg/L. Total uranium concentration greater than or equal to 0.03 mg/L.
- 4 Summed CY 2002 concentration of a VOC group (see below) greater than or equal to 5 μg/L.

Ethenes = Summed chloroethenes (PCE, TCE, 12DCE, 11DCE, 11DCE, vinyl chloride)

Ethanes = Summed chloroethanes (111TCA, 11DCA, chloroethane)

Methanes = Summed chloromethanes (carbon tetrachloride, chloroform, methylene chloride)

Petroleum = Summed petroleum hydrocarbons (benzene, toluene, ethylbenzene, dimethylbenzene)

Note that individual compounds have different long-term concentration trends at well GW-071.

Maximum CY 2002 gross alpha activity greater than or equal to 15 pCi/L. Maximum CY 2002 gross beta activity greater than or equal to 50 pCi/L.

Table B.5 Concentration trends for the principal contaminants detected at CY 2002 sampling locations in the Upper East Fork Poplar Creek Hydrogeologic Regime

CY 2002		(and Long-Te increasing, =	rm Trend ² - = decreasing	g)	
Sampling Location ¹	Inor	ganics ³		V	OCs 4		Radioa	ctivity ⁵
Location	Nitrate	Uranium	Ethenes	Ethanes	Methanes	Petroleum	Alpha	Beta
GW-108	—		0		0		0	Γ
GW-151			Е		[-
GW-153					0,-			
GW-154								0
GW-170			0		0			
GW-193		•				0		
GW-204		_					0	
GW-219		0					0	
GW-220		•						
GW-223		Г	- ,[
GW-230		-	0					
GW-251	_		0		0			
GW-253	0		[0		0	
GW-380			-		0			
GW-381			_		-		•	
GW-382			0		○,━			
GW-383			Е					
GW-605		0	0		0		0	
GW-606	Γ		0		_			
GW-618	Q		0					
GW-620			-			0		
GW-633	 		○, [0	○,[_
GW-658				0		0		
GW-686			0					
GW-689		0					0	
GW-698	0		○, [0			
GW-722-14			_		-			
GW-722-17			_		-		•	
GW-722-20			_		-			
GW-722-22			-		-			
GW-722-26						0		
GW-722-32							Q	
GW-733					-			
GW-762		•		0			•	
GW-763			0				0	
GW-769		•	Ε		<u> </u>			
GW-770			<u>-</u>		0			
GW-775			0					
GW-782			0	0			0	
GW-791			0		,		<u>.</u>	
GW-832					_			

Table B.5 (continued)

CY 2002		Contaminant Type and Long-Term Trend ² (O = indeterminate, \(\bigcup \) = increasing, \(- \) = decreasing)								
Sampling Location ¹	Inorg	Inorganics ³ VOCs ⁴ Radioactivity ⁵								
Location	Nitrate	Uranium	Ethenes	Ethanes	Methanes	Petroleum	Alpha	Beta		
LRSPW				0 .						
OF 51			0		0					
OF 200		0	0		0		•	•		
STATION 17				0						
STATION 8		0			0		0			

- Only CY 2002 sampling locations with contaminated samples (see criteria below) are included on the table. The exit pathway/perimeter monitoring locations are in bold typeface. Uncontaminated samples (contaminant levels below the criteria) were collected from the following locations in CY 2002: 55-1B, GHK2.51ESW, GHK2.51WSW, GW-169, GW-170, GW-171, GW-172, GW-207, GW-208, GW-232, GW-349, GW-350, GW-687, GW-722-06, GW-722-10, GW-722-30, GW-722-33, GW-735, GW-744, GW-747, GW-750, GW-776, GW-816, NPR07.0SW, NPR12.0SW, NPR23.0SW, SCR7.1SP, and SCR7.8SP.
- 2 Trend types were interpreted from data tables or plots of concentration changes over time.
 - . Not a contaminant (criteria defined below, in notes 3, 4, and 5).
 - Indeterminate trend: insufficient data, fairly stable trend, affected by sampling methods or highly fluctuating with no clear upward or downward trend.
 - Q Elevated concentration, unsupported by other samples from the location (suspect data)
 - Generally decreasing trend.
 - Generally increasing tend.
- 3 CY 2002 nitrate concentration greater than or equal to 10 mg/L. Total uranium concentration greater than or equal to 0.03 mg/L.
- 4 Summed CY 2002 concentration of a solvent group (see below) greater than or equal to 5 µg/L.

Ethenes = Summed chloroethenes (PCE, TCE, 12DCE, 11DCE, 11DCE, vinyl chloride)

Ethanes = Summed chloroethanes (111TCA, 11DCA, chloroethane)

Methanes = Summed chloromethanes (carbon tetrachloride, chloroform, methylene chloride)

Petroleum = Summed petroleum hydrocarbons (benzene, ethylbenzene, toluene, and dimethylbenzene)

Note that individual compounds have different long-term concentration trends at wells GW-153, GW-223, GW-382, and GW-698.

Maximum CY 2002 gross alpha activity greater than or equal to 15 pCi/L. Maximum CY 2002 gross beta activity greater than or equal to 50 pCi/L.

Table B.6 Concentration trends for contaminants detected at CY 2002 sampling locations in the Chestnut Ridge Hydrogeologic Regime

CY 2002			Contar	ninant Type	and Long-T	erm Trend ²		
Sampling	I	norganics	3		VOCs 4		Radioa	ctivity 5
Location 1	Arsenic	Nickel	Grout	Ethenes	Ethanes	Methanes	Alpha	Beta
GW-144				0				
GW-177				[○,[
GW-205			0					0
GW-302		0						
GW-305		0		[[
GW-339		0				0		
GW-522				0				
GW-544								
GW-757			0					
GW-796					0			
GW-798]				
MCK 2.0	0							
MCK 2.05	0							

- Only CY 2002 sampling locations with contaminated samples (see criteria below) are included on the table. The exit pathway/perimeter monitoring locations are in bold typeface. Uncontaminated samples (contaminant levels below the criteria) were collected from the following locations in CY 2002: 1090, GW-141, GW-142, GW-143, GW-145, GW-156, GW-159, GW-203, GW-217, GW-221, GW-231, GW-241, GW-301, GW-514, GW-521, GW-539, GW-540, GW-542, GW-543, GW-557, GW-560, GW-562, GW-564, GW-608, GW-709, GW-731, GW-732, GW-797, SCR1.25SP, SCR1.5SW, SCR2.1SP, SCR2.2SP, SCR2.2SW, SCR3.4SP, SCR3.5SP, SCR4.3SP, SCR4.4SW, SCR5.1SP, SCR5.2SP, SCR5.2SW, and SCR5.4SP.
- 2 Trend types were interpreted from data tables or plots of concentration changes over time.
 - . Not a contaminant (criteria defined below, in notes 3, 4, and 5).
 - Indeterminate trend: fairly stable trend or the contaminant is a potential artifact.
 - Generally decreasing trend.
 - **C** Generally increasing tend.
- 3 CY 2002 trace metal concentration that exceeds the applicable MCL (Arsenic > 0.01 mg/L; nickel > 0.1 mg/L), or indication of grout contamination (pH > 9 and potassium > 10 mg/L).
- 4 Summed CY 2002 concentration of a solvent group (see below) greater than 0 μ g/L (excluding trace levels of common laboratory reagents).

Ethenes = Summed chloroethenes (PCE, TCE, 12DCE, 11DCE, 11DCE, vinyl chloride)

Ethanes = Summed chloroethanes (111TCA, 11DCA, chloroethane)

Methanes = Summed chloromethanes (carbon tetrachloride, chloroform, methylene chloride)

Note that individual compounds have different long-term concentration trends at wells GW-177 (111TCA is indeterminate and 11DCA is increasing)

Maximum CY 2002 gross alpha activity greater than or equal to 15 pCi/L. Maximum CY 2002 gross beta activity greater than or equal to 50 pCi/L.

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